

The Effects of Hydrolyzed Electrostatic Powder Coating Wastes on Fluidity and Density of Glass Fiber Reinforced Polypropylene

Yilmaz Kismet
Munzur University Department of Mechanical Engineering, Tunceli, Turkey
E-mail: ykismet@munzur.edu.tr

Abstract
In this study, synthetic wastes of different proportions have been used to improve the fluidity of glass fiber-reinforced polypropylene (GF/PP) during extrusion and plastic injection molding. The wastes used were mixed in GF/PP at the rate of 3%, 5% and 7% by weight and their flowability was determined by using melt flow device (MFI) under the effect of 10 kg weight at 230 °C. Depending on the type and ratio of waste used, the melt flow index of GF/PP is extracted and the effects of wastes on fluidity are explained by graphs. Also, changes in the densities of the formed mixtures were determined and shown in graphs. The effect of electrostatic powder paint materials in three different thermoset characters, which are used as synthetic wastes, has improved the fluidity of GF/PP by positively affecting under the same temperature and pressure. However natural additives have negatively affected the fluidity of GF/PP.

Keywords: polyvinyl chloride, powder coating waste, recycling, melt flow index, thermal properties.

Introduction

Although advancing technological developments allow the development of alternative materials in the industry, meeting the ever-increasing human needs and removing/disposing of the resulting consumption wastes is one of the most important problems for the states. Therefore, it is extremely important to recycle natural or synthetic wastes nowadays. The deterioration processes -which last for centuries- of the wastes in nature, especially polymer and polymer matrix materials, causes the destruction of nature and the negative effects of many living things.

Polymers are important alternative materials that have completely entered all areas of our Nowadays, the most important reasons for the widespread use of polymers are that they are easy to find, low-cost and easy to produce. Therefore, polymer or polymer matrix materials are frequently preferred in many areas from the food sector to the communication sector, from the automotive industry to the health sector.

The most important group of polymers consists of thermoplastics. Thermoplastics soften and flow when heated, and solidify again when cooled. In this way, it is possible to melt a thermoplastic repeatedly without causing any chemical degradation and then to re-solidify it. Thermoplastics with covalent interchain van der walls in the chain are obtained by the polymerization reaction. Thermoplastics are structurally divided into two groups as amorphous and crystalline and the most important group consists of crystalline polyolefins. The most important thermoplastics in polyolefins are polyethylene and polypropylene and are used in the production of many thermoplastics that we use in our daily life. Polypropylene is obtained as a result of the polymerization reaction of the propene monomer. Polypropylene is a thermoplastic with high moisture and heat resistance, resistant to chemicals, low density, and good surface hardness. As in many thermoplastics, different organic and inorganic additives are used in polypropylene to improve mechanical, thermal, physical properties and so on. Materials of different characteristics such as wood shavings, glass fiber, calcium carbonate, talc, kaolin, seaweed, rape are also preferred for improving the properties of polypropylene.

Electrostatic powder coating technology is used since 60 years not only in coating of metal material, but also in coating aluminum, polymer and materials for decorative purposes today. The contents of powder coating comprise resin, stiffener, fillers, colorant and additives. Nine different systems have been developed for electrostatic powder coating. These systems have been divided into mainly two groups as thermoplastic and thermoset. Thermoset system constitute approximately 90% of today's all powder coating production because of low baking temperatures and thin film thickness when compared to

thermoplastic systems. Powder coating does not contain solvents as opposed to wet paint. Since it contains no solvent, harmful gas emissions were not released during powder coating applications. Because of high productivity, low energy costs and environment friendly properties powder coating is becoming more prevalent.
Before the material is coated with powder coating, the surfaces are cleaned with mechanical or chemical techniques. Afterwards, powder coating is sprayed onto these surfaces using a spray gun. Powder coating is charged in spray guns using two different methods of “tribo” or “corona” charging. In both cases, an electrostatic gravitation occurs between the powder particles and the material to be coated enables the adsorption of powder coating particles to the material surface. Later on the material were cured under certain temperatures and durations based on the properties of the electrostatic powder coating used. Usually firing temperatures vary between 130 and 240^{o}C for thermosetting powder coating, while the materials are cured under higher temperatures, between 300 and 400oC for thermoplastic powder coating. While worldwide production figure of powder coating material was 1.5 million tons as of 2010, this rate reached approximately million tons in 2018.
Especially, glass fiber is often preferred for improving the mechanical properties of polypropylene and glass fiber reinforced polypropylene (GF/PP)is produced in many areas of the industry. Glass fibers (GF) are the most common reinforcement for polymeric matrix composites. Their advantages are the relationship between their low cost, high tensile strength, high chemical resistance, and insulating properties. But their disadvantages are low tensile modulus, relatively high specific gravity, sensitivity to abrasion during handling, low fatigue resistance, and high hardness. However, there are problems in the binding mechanism just as between many additives and the matrix, similar problems exist between glass fiber and polypropylene as well. Hydrolized powder coating wastes were also used in this study to improve the flowability and density of glass fiber reinforced polypropylene.

Material and Methodology

Material

The matrix material used in the studies is glass fiber reinforced polypropylene. The reinforcement elements used are thermoset powder coating wastes. These wastes belong to epoxy, epoxy/polyester and polyurethane systems and they were hydrolyzed.

Experimental Studies

The fillers used in the studies were first hydrolyzed separately in a mixture of pre-prepared water and alcohol. During the hydrolysis process, the waste materials were kept in the alcohol mixture for 30 to 60 minutes at approximately 100 °C. In order to effectively hydrolyze the powder coating wastes, a very low amount of alcohol was used and thus, it was possible to hydrolyze the powder coatings as a whole.
The prepared hydrolyzed powder coats were separately supplemented into GF/PP in 3%, 5% and 7% by weight. The mixtures were prepared mechanically and prepared by weighing approximately 6 to 8 grams of the sample from each mix proportion for the experiment. The changes in the melt flow indexes of these mixtures were carried out by using "JPT EQUIPMENT brand XRL 400A model" MFI melt flow device in Munzur University Mechanical Engineering Polymer Technologies laboratory. The prepared mixtures were discharged from the feeding orifice of the device into the heating chamber and pressed with a piston to allow to dissolve in the heating chamber at 230 °C. During this process, which lasted for approximately 3 minutes, a preload of 0,325 kg was applied on the piston. After observing the flow of the mixture from the fine-tipped nozzle located beneath the heating chamber, the main load was applied to the piston and the mixture was forced to flow under a total force of 10 kg. With the weight effect, the piston moves in the vertical direction and the material flows through the nozzle. With this movement of the piston, the measuring handle of the device moves after a period of time and the measurement starts by starting the device. The material flowing through the nozzle of the device was cut every 30 seconds with a pair of scissors located on the nozzle. This cutting process continued throughout the measuring range (30 mm). The cut pieces obtained from the experiment were weighed on a precision scales and the average weight values were measured. The result was entered into the relevant area of the device's digital panel and the fluidity and density values of the mixtures were automatically determined by the device. Fluidity values were determined both in mass and in volumetric and were shown in graphs.

Results and Discussion

Figure 1 shows the change in melt mass flow index of GF/PP depending on three different filler amounts.

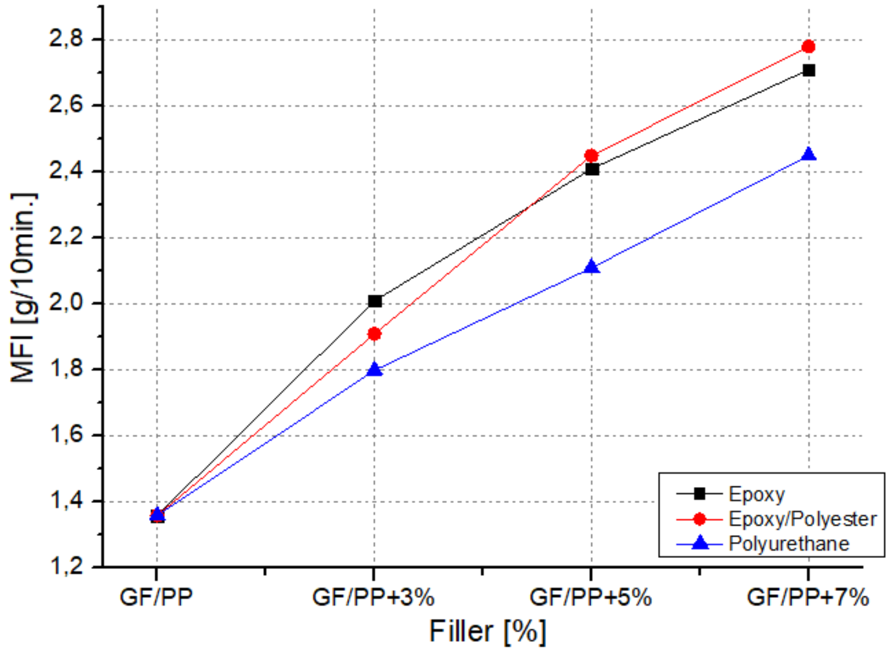

Figure 1. The melt mass flow index change of GF/PP depending on the filler amount.

According to the graph above, all three fillers have a positive effect on the fluidity of GF/PP, allowing for better fluidity under the influence of the same temperature and weight. While the melt flow value of pure GF/PP was 1.38 g/10 min, this value was measured as 2.78 g/10 min with the highest viscosity value in GF/PP containing 7% epoxy/polyester filler. It was determined as 2.45 g/10 min in GF/PP mixture containing 7% polyurethane filler and 2.71 g/10min in GF/PP mixture containing 7% epoxy filler.

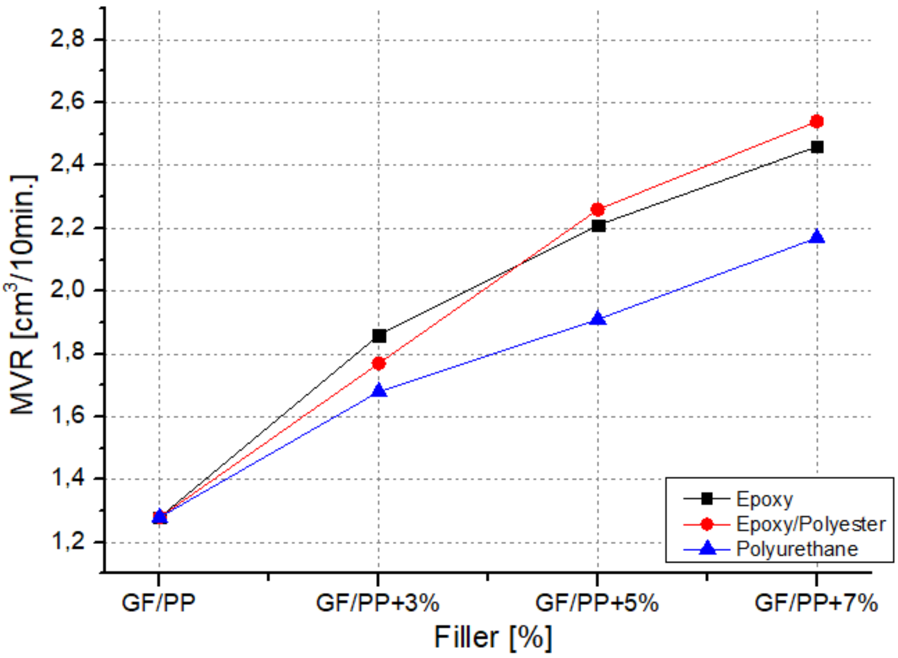

Figure 2. The volumetric melt flow index change of the GF/PP depending on the filler amount.

In Figure 2, the changes in the volumetric flow indexes of the mixtures belong to the same filler type and filler ratios are given. The temperature and weight values applied in the mass flow measurement are the same here and it is seen that the volumetric viscosity values increase depending on the amount of filler. While the volumetric flow index of pure GF/PP was 1,28 g/cm3, this value reached a maximum of 2.54 g/cm3 in the mixture containing 7% epoxy/polyester filler. In the GF/PP mixture containing epoxy filler at the same rate, the volumetric flow index was 2.46 g/cm3 and in the GF/PP mixture containing polyurethane filler, it was measured as 2.17 g/ cm^3.

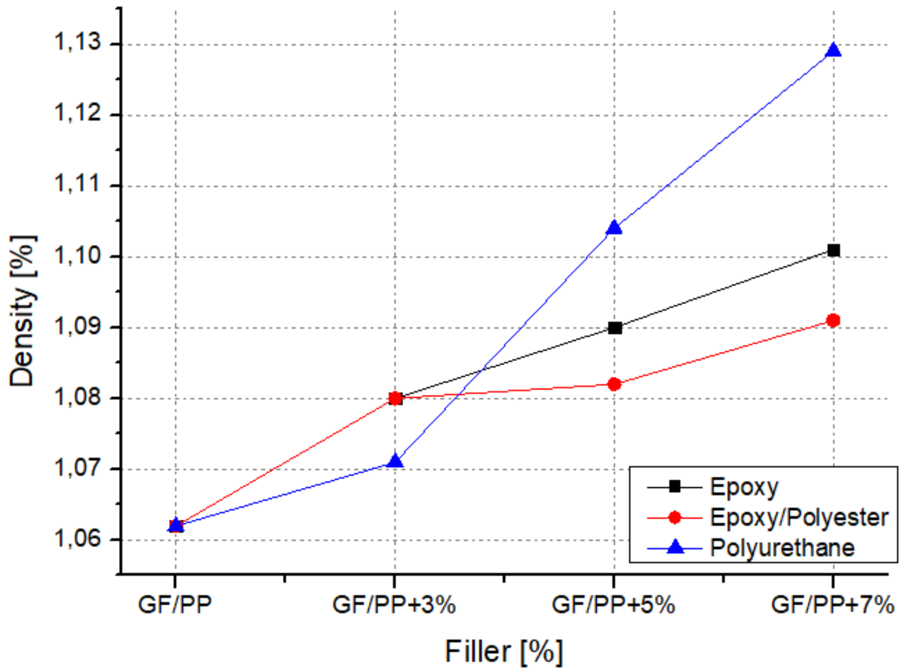

Figure 3. The change in the density of GF/PP depending on the filler amount.

In Figure 3, the density variations of the mixtures obtained are given. This value is calculated automatically by the MFI device. It is also possible to calculate with the ratio of mass flow index to volumetric flow index. As in both the mass fluidity and the volumetric fluidity measurements, the density value increased with increasing amount of filler in the mixture. The reason for this increase is that the mass flow index of the mixture that is flowing in the same period under the influence of massively constant temperature and weight is higher than the volumetric flow index. While the density of pure GF/PP was 1,062 g/cm3, this value was found to be 1,129 g/cm3 in samples containing 7% polyurethane filler. The density of the mixture containing 7% epoxy filler was measured as 1,101 g/cm3 and the density of the mixture containing epoxy/polyester filler at the same rate was measured as 1,091 g/cm3.

Conclusion

In this study, it was determined that the fluidity and density values of GF/PP showed significant differences depending on the hydrolyzed electrostatic powder paint wastes of thermoset character. The mixtures formed by the increased amount of hydrolyzed electrostatic powder coat waste in GF/PP became more fluid and denser. The reason behind the fluidity is that the temperature at which the experiment takes place (230 ºC) is at a temperature close to the furnace temperature of the powder coating wastes and that the powder coatings have a viscous character at this temperature. Also, since the wastes are hydrolyzed without mixing in GF/PP, they can remain in a viscous state at the test temperature for a longer period of time than normal powder coatings. This allows the fluidity of the mixture to be maintained for a longer period of time. In addition, since the density of the powder coatings is higher than the density of GF/PP, the mixtures became more intense.

Acknowledgements
This study was supported by Scientific and Technological Research Council of Turkey (TUBITAK) (Project Number: 213M461). The authors are gratefully for this financial support.

References

Kaiser. W., *Polyolefine, Kunststoffchemie für Ingenieure*, Carl Hanser Verlag., Wien, 2006.

Michaeli. W., *Verarbeitungsverfahren für die Kunststoffe, Einführung in die Kunststoffverarbeitung*, Vicentz Network., Wien, 2006.

Ravve, A., *Principles of Polymer Chemistry*, Springer., New York, 2000.

Nannetti, P., *Lack für Einsteiger*, Vincentz Network., Hannover, Germany, 2009.

Pietschmann, J., Industrielle Pulverbeschichtung. Wiesbaden: View&Sohn Verlag; 2003.

Kısmet, Y., İstek, H., Tunceli İlinde Geri Dönüşüm Çalışmaları ve Elektrostatik Toz Boya Atıklarının Geri Kazanımı. 4th Internationale Regional Development Conferance, Tunceli, Turkey, 2017.

Kısmet, Y., Effects of Hydrolyzed electrostatic powder coating wastes on fluidity and density of polyolefins. *Sigma Journal Engineering and National Science*, 33 (2015), 3, pp. 377-383.

Kismet, Y., Investigation of the changes in melt flow indexes (MFI) and densities of polyamide 6 (PA6) and polyoxymethylene (POM) related with hydrolyzed powder coating waste amount. *Pamukkale University Journal of Engineering Science*, 22 (2016), 4, pp. 241-245.

Gheno, G., Ganzerla, R., Bortoluzzi, M., Paganica, R., Determination of degradation kinetics of two polyester thermosetting powder coatings using TGA and colorimetric analysis. *Progress in Organic Coating*, 78 (2015), pp. 239-243.

Taurinoa, R., Sciancaleporeb, C., Collinia, C., Bondic, M., Bondiolia, F., Functionalization of PVC by chitosan addition: Compound stability and tensile properties. *Composites Part B*, 149 (2018), pp. 240-247.

Naim, AA., Alnaim, N., Sobhy SI.,, Metwally SM., Effect of gamma irradiation on the mechanical properties of PVC/ZnO polymer nanocomposite. *Journal of Radiation Research and Applied Sciences*, 10 (2017), pp. 165-171.

Kismet, Y., Change of Mechanical Properties of Powder Recyclate Reinforced Polyolefin Based on Gamma Radiation, *Polymers*, 9 (2017), pp. 387.

Etcheverry M and Barbosa S E., Glass Fiber Reinforced Polypropylene Mechanical Properties Enhancement by Adhesion Improvement, Materials, 5 (2012), pp. 1084-1113.