EFFECT OF LENGTH OF GLASS FIBERS IN RECYCLED POLYPROPYLENE ON MECHANICAL PROPERTIES

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This article investigates the effect of recycled material particle size on the resulting mechanical properties of products. The product material was polypropylene with glass fibers. Recycled material was prepared by mechanical way of recyclation, then it was categorized by sieve analysis to different size of particles. After preparation, the samples were subjugated to mechanical tests. The samples were subjected to the Charpy impact test, the hardness of Shore D test. Testing was conducted at ambient temperatures. The effect of reprocessing of the material is mainly represented by fiber shortening. As a result, considerable reduction of mechanical properties can be observed.

KEYWORDS

recycling, sieving, particle size, glass fiber, polypropylene, tensile properties

1 INTRODUCTION

Current trends in production allow mass production of polymer products at affordable prices, which strengthened their role among other construction materials. With regard to the pressure of the general public and experts on environmental aspects of production, the recycling area gains more importance. Some types of polymers can be classed as easily recyclable but manufacturing companies are not capable of producing polymer with exactly the same properties as the original product. Therefore, recycled polymer is in the manufacture added only in a certain ratio. Thus, it is possible to process discarded products and waste from production. Generally speaking, during manufacture of the stressed products can be added very little or no share of recycled material. In cases where it is not needed to meet these requirements, product with a higher proportion of recycled material can be produced. In practice it is common that some non-structural visual parts are made entirely from recycled materials.

One of the reasons leading plastics processors and manufacturers of machinery for the preparatory process for recycling is currently relatively high price of plastic. Modern states strive to lead companies to recycling by legislation and therefore seek to provide benefits for processors of recycled material. Today, there is already many machines and devices on the market that are designed specifically for processing waste into regenerated material.

The impact of man-made polymers on the environment is a problem of high priority in most industrialized countries. Mainly due to a build-up of disposed waste in landfills, and due to campaigns in the press about mistakes made in the management of waste treatment, public opinion is focusing on this problem. The fact that the corresponding percentage by volume is higher, due to the low packing density of wastes, makes the problem more visible.

Mechanical recycling is limited by the compatibility between the different types of polymers when mixed, as well as by the fact that the presence of small amounts of a given polymer dispersed in a matrix of a second polymer may dramatically change the properties of the latter, hindering its possible use in conventional applications. Another difficulty with mechanical recycling is the presence in plastic wastes of products made of the same resin but with different colours, which usually impart an undesirable grey colour to the recycled plastic.

Glass fibers are one of the most cost-effective reinforcements for plastics. Chopped glass fibers can be compounded with thermoplastics to obtain products with improved property sets. They are easily obtainable from a range of manufactures and their production process is quite energy efficient, so that their use into products does not significantly affect the environmental performance.

Mechanical recycling of thermoplastics materials with glass fibers consists of granulating and re-molding, without separating reinforcing fibers from matrix. Then the material is reused still as composite. The fiber length distribution and the bonding between the glass fibers and the polymer are affected by the injection molding process. Bonding can be improved by using coupling agents or by incorporating recycled material into virgin material, but fiber shortening constitutes an important issue for safely using recycled fiber reinforced materials.

2 EXPERIMENT

This paper deals with analysis of effect of particle size of recycled material on the mechanical properties. The goal is to perform an experiment in which the products of the studied polymer will be crushed to crushed material (recycled material) and then reprocessed into new products. These are then subjected to tensile mechanical testing.

2.1 Grinding

At the start products was produce by injection molding technologies. Thus these parts were used to receive recycled material. Production of parts was followed by grinding. Grinding of PP waste was conducted on the knife mill GK 2218 from producer Maskain AB Rapid. Sieve inside of knife mill contains holes with diameter 4mm. The output of the knife mill was mixed crushed material containing many particles of various sizes up to a fine powder. It is the dust and very fine particles, which presents a certain risk for further processing and changing of polymer properties.

2.2 Sifting

Sifting of grinded material was carried out after grinding. The purpose of the sifting was to group the particles of certain sizes of non-sieved crushed recycled material. Sieving was carried out on laboratory sieve shakers AS 200 Basic. The sifting device had sieves with size of their holes 4 mm, 3 mm, 2 mm, 1 mm and a bowl for particles with size smaller than 1 mm.

2.3 Specimens

The specimens were prepared by the injection molding technology on the injection molding machine Arburg Allrounder 470H. Each of the specimens were left to condition for 24 h before testing by the following methods.

2.4 *Composition of tested mixtures*

Different compositions were prepared for the measurements of tested mixtures with differing sizes of sieved particles.

- Virgin PP - material directly from the manufacturer which has not yet been processed in any way, it is taken as a referential material, length of cylindrical granules is 3.5mm.
- Non-sieved crushed PP – this recycled material is collected directly from the knife mill, contains particles of all sizes, from large particles to dust particles and therefore is heterogeneous.
- PP 1 – 0 mm – sieved recycled material with a particle size from 1 mm to 0 mm, containing very small to dust particles and therefore the shortening of the fibers is the greatest. (Fig. 1)

Figure 1. PP 1 – 0 mm mixture

- PP 2 – 1 mm – sieved recycled material with a particle size from 2 mm to 1 mm.
- PP 3 – 2 mm – sieved recycled material with a particle size from 3 mm to 2 mm.
- PP 4 – 3 mm – sieved recycled material with a particle size from 4 mm to 3 mm, these particles are similar in size as the original virgin granule.
- PP 5 – 4 mm – sieved recycled material with a particle size bigger than 4 mm – this particles stay on sieve with holes 4 mm and chopped fibers are at least due to the length size of the polymer particles (Fig. 2)

Figure 2. PP 5 – 4 mm mixture

Table 1. Tested mixtures

Composition of tested mixtures	Particle size [mm]
Virgin PP + 30 % glass fiber	granule
PP 5 - 4mm	5 > x > 4
PP 4 - 3mm	4 > x > 3
PP 3 - 2mm	3 > x > 2
PP 2 - 1mm	2 > x > 1
PP 1 - 0mm	1 > x > 0
Non-sieved crushed PP	All size of particles

Fig. 3 shows the weight ratio of particle size of the total grinded mixture. It shows that the largest proportion of the recycled particles between 4-3 mm, of the total volume of them present in almost half. Particles 3-2 mm representing a further 41% by weight. Other particles represent only a small percentage. Finally, the dust particles occupy only 1% of the total weight.

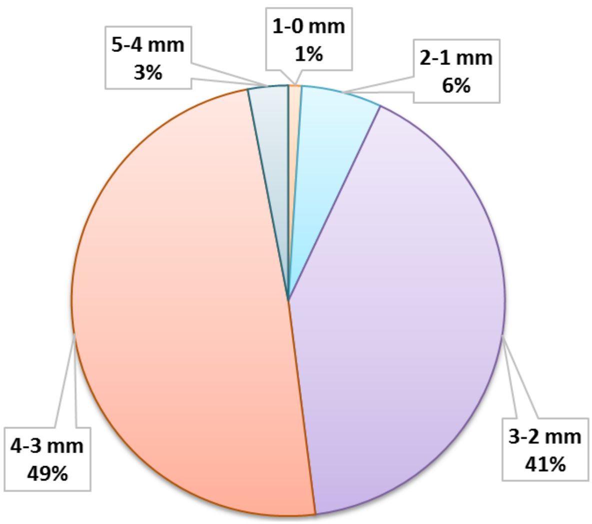

Figure 3. Weight ratio of particle size of the total grinded mixture

3 TESTED MATERIAL

Polymer used for this work is an injection molding grade Syntegum 2030 AFV. It is compound on homopolymer polypropylene, reinforced with 30 percentage chemical couple glass fibers. And this PP is suitable for the production of high-technological products, which in normal working conditions are submitted to high temperatures and considerable mechanical stress.

4 TESTING

The first mechanical test in order was notch toughness test alias Charpy impact test. Testing was performed on the Resil Impact Junior testing machine from company CEAST. The tests were carried out according to ISO 179. Preparation of individual samples proceeded before each testing. It consisted of making of notch in specimens. Notch was shaped into V-shape with depth of 2 mm.

Shore D hardness test was performed on the hardness tester from the OMAG company with type marking ART 13. The test surface of specimens must be cleaned before test. Testing was performed according to EN ISO 868. First, the sample was placed in a rack of hardness tester and then indenter started pressing to the surface of the test specimen. After the time interval of 5 seconds display shows the value of hardness Shore D. Hardness Shore D is determined by the depth of penetration of the indenter and the size of the scale is then 0-100 Shore.

5 RESULTS

All graphs shows the values in percentages, while virgin PP represents 100%. Other values are derived from the nominal values.

5.1 Charpy impact toughness

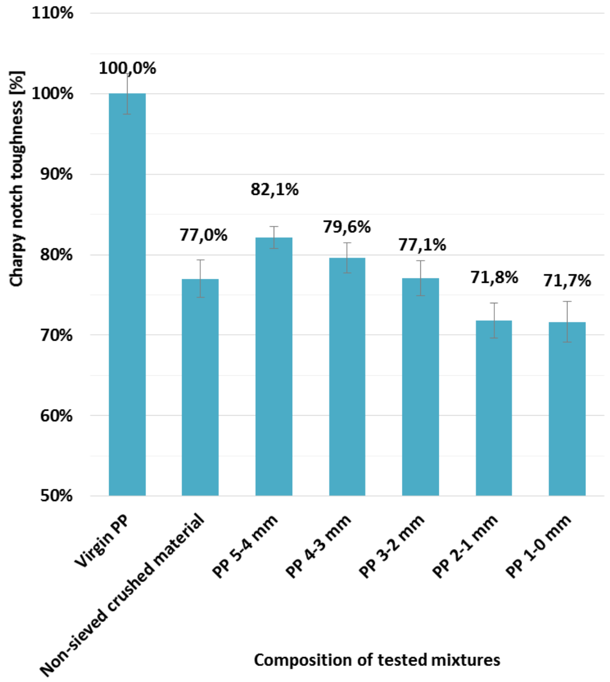

Figure 4. Weight ratio of particle size of the total grinded mixture

In Fig. 4 it can see the resulting measurement values of Charpy notch toughness (6.8 kJ/m^2) at 23 ° C. The highest value of impact toughness was measured on the test specimen from the virgin material. Notched impact toughness was lower by approximately 20% on samples with a particle size of 5 – 4 mm and 4 – 3 mm. Toughness was measured lower about 23% on samples with a particle size of 3 – 2 mm and non-sieved crushed polymer. Almost identical and the lowest impact toughness was achieved on samples with a particle size of 2 – 1 mm and 1 – 0 mm, which was about 28% lower compared to the virgin material.

5.2 Charpy breaking force

The greatest breaking force 528 N can be seen for the test samples from the virgin material (Fig. 5). The second highest force was measured for the test sample with a particle size of 5 – 4 mm, the force was lower about 4%. Breaking force was measured lower approximately 8% for samples with a particle size of 4 – 3 mm and 3 – 2 mm.

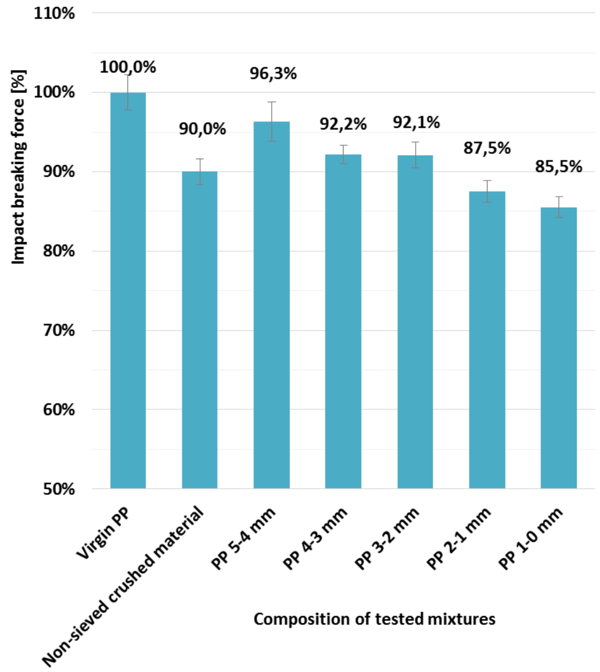

Figure 5. Breaking force F_m

Force was lower about 10% for the sample of non-sieved crushed polymer. The lowest breaking force were measured for samples with particle size 1 – 0 mm and 2 – 1 mm, values were approximately 15% lower compared to the virgin material.

5.3 Hardness Shore D

The Fig. 6 shows maximum and minimum value of hardness differ only approximately 3.5% from each other. The highest hardness (72.6 ShD) was measured on the virgin polypropylene.

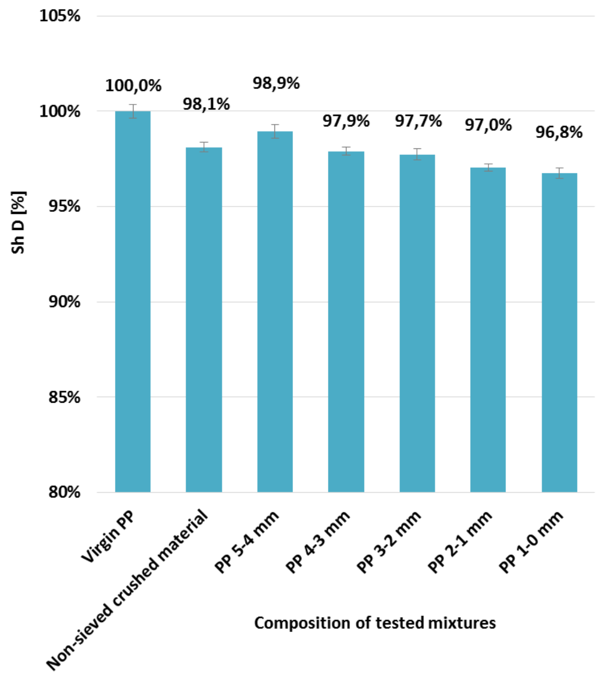

Figure 6. Hardness Shore D

Hardness value of recycled particle sizes of 5 – 4 mm was closest to virgin material. The lowest hardness was measured on recycled particle size 1 – 0 mm. The hardness gradually increases with rising of recycled particle size.

6 CONCLUSIONS

This paper describes the influence of particle size of recycled polypropylene containing 30% glass fibers on the mechanical properties of the resulting products.

Test samples were subjected to Charpy impact test and also the Shore D test. The tests were carried out at room temperature of 23 °C. Seven mixtures of test samples were prepared for the measurement of mechanical properties. These samples were virgin polypropylene, non-sieved crushed PP, samples with a particle size of 5 – 4 mm, 4 – 3 mm, 3 – 2 mm, 2 – 1 mm and 1 – 0 mm.

Test samples with a particle size of 5 – 4 mm showed the smallest reduction properties. Mixtures of non-sieved crushed material, 4 – 3 mm and 3 – 2 mm still do not show such a large difference in the mechanical properties. Samples with a particle size of 2 – 1 mm and 1 – 0 mm have in most cases differences a little more noticeable in the mechanical properties. The lowest measured results and consequently the lowest mechanical properties were measured on test specimens of recycled particle size of 1 – 0 mm.

Measurements confirmed that the usage of recycled material reduces the mechanical properties. Usage in components where it is necessary to have guaranteed mechanical properties it is not so appropriate. The glass fibers in mixture with recycled dust particles have almost no effect on the final properties. On the other hand, usage of recycled filled material would be economically advantageous in parts with lower demands on the use. This would lead to a reduction in costs for the purchase of material and the associated production of a new polymers.

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REFERENCES

[Behalek 2013] Behalek, L. and Dobransky, J. Conformal cooling of the injection moulds. Applied Mechanics and Materials. Vol. 308 (2013). pp. 127-132. ISSN 1660-9336.

[Brandrup 1996] Brandrup, J. (ed.): Recycling and recovery of plastics, Munich, Hanser Verlag, 1996.

[Drobny 2003] Drobny, J. G. Radiation Technology for Polymers, CRC Press, New York, (2003).

[Dobransky 2016] Dobransky, J. et al. Determination of the EOS Maragingsteel MS1 Material Resistance at Low Temperatures. Metalurgija. Vol. 55. No. 3 (2016). pp. 449-452. ISSN 0543-5846.

[Goodship 2007] Goodship, V., Introduction to plastics recycling. 2nd ed. Shawbury, U.K.: Smithers Rapra, 2007, 174 p. ISBN 978-1-84735-078-7.

[La Mantia 1993] La Mantia, F. P. Recycling of plastic materials. Toronto: ChemTec Pub., 1993, vi, 189 p. ISBN 18-951-9803-8.

[Manas 2013] Manas, D., et al. Effect of Beta Irradiation on Morphology and Microhardness of Polypropylene Thin Layers. Thin Solid Films 530 (2013).

[Manas 2015] Manas, D. et al. Effect of low doses beta irradiation on micromechanical properties of surface layer of injection molded polypropylene composite. Radiation Physics and Chemistry, 114, (2015), pp. 25-30.

[Ovsik 2012] Ovsik, M. et al. Irradiated Polypropylene Studied by Microhardness and WAXS, Chemicke listy, 106 (2012), 507-510.

[Ovsik 2013] Ovsik, M. et al. Micro-hardness of glass fiber-filled PA6 influenced by beta irradiation. International Journal of Mechanics, 7 (4), (2013), pp. 500-507.

[Ovsik 2014] Ovsik, M. et al. Micro-hardness and morphology of LDPE influenced by beta radiation. Key Engineering Materials, 606, (2014), pp. 253-256.

[Ovsik 2015] Ovsik, M. et al. Micro-indentation test and morphology of electron beam irradiated HDPE. Key Engineering Materials, 662, (2015), pp. 189-192.

[Ragan 2012] Ragan, E. et al. Dynamic of Taking out Molding Parts at Injection Molding. Metalurgija. Vol. 51. No. 4 (2012). pp. 567-570. ISSN 0543-5846.

[Scelsi 2011] Scelsi, L. et al. A Review on Composite Materials Based on Recycled Thermoplastics and Glass Fibres. Plastics, Rubber and Composites. (2011), vol. 40, ISSN: 1465-8011.

[Senkerik 2014] Senkerik, V. et al. Comparison of mechanical properties of different particle sizes of recycled polycarbonate at higher temperature (2014) International Journal of Mechanics, 8 (1), pp. 268-275.

[Senkerik 2014] Senkerik, V. et al. Size effect of recycled material to tensile properties of PC
(2014) Advanced Materials Research, 1025-1026, pp. 278-282.

[Senkerik 2016] Senkerik, V. et al. Effect of recycled particle size to micro-hardness properties of styrene acrylonitrile (2016) Defect and Diffusion Forum, 368, pp. 154-157.

[Skrobak 2014] Skrobak, A. Mechanical properties of rubber samples (2014) Key Engineering Materials, 606, pp. 249-252.

[Stanek 2011] Stanek, M. et al. Optimization of Injection Molding Process, International Journal of Mathematics and Computers in Simulation, Volume 5, Issue 5, 2011, p. 413-421

[Zamfirova 2010] Zamfirova, G. et al. Microindentation study of Electron Beam Irradiated Polyamide Samples. Chemicke Listy, 104 (2010), 283-286.

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