

The multiaxial behavior of filled polypropylene parts by drop-weight impact test

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Abstract. This study deals with the multiaxial behaviour of reinforced polypropylene with 30 % of glass fibre (PP30GF) and virgin polypropylene (PP). The impact behavior of these two materials is very needed to know for the possible modification of these two materials to obtain the better material properties. The injection moulded PP, and PP30GF samples were subjected to the penetration test at different set potential energies, and the results were subsequently evaluated and discussed. It was found out that PP has better behaviour at the multiaxial stress than PP30GF. It is possible to claim that for the application more demanding to the impact loading, pure PP is more suitable choice of the polymeric material.

1 Introduction

Polypropylene (PP) is a thermoplastic semi-crystalline polymer belonging to the polyolefin family owning good mechanical and dielectric properties. This polymer is considered as a commodity polymer, and it is very often used in the area of the automotive, chemical and the electrical industry for the production of electrical insulation thanks to its low dielectric loss and very good heat resistance [1-4]. In comparison to the other polyolefin, e.g. polyethylene, PP has the higher mechanical resistance and rigidity because of its higher crystallinity and point of melting [5]. Despite good mechanical properties of PP, it is possible to obtain better mechanical properties using fiberglass reinforcement as a modification. Organofunctional silane compounds together with the graft or block polyolefin copolymers are used to promote the adhesion of reinforced plastics with fiber. This compound together with PP was twin-screw extruded, immediately quenched in water and cooled in air to the ambient temperature. The samples for testing were injection moulded, and subsequently, mechanical and thermal properties were measured. The results showed that samples from blend above-mentioned showed an increase in tensile modulus, bending modulus, tensile strength, bending strength and notched impact strength compared to pure PP. The data also showed that thermal stability of modified PP was better in comparison to the pure one [6].

The effort to obtain light-weight high-strength reinforcement PP led the scientists to create the blend from PP, hollow glass microspheres and short bamboo fibre. After preparation of the blend and samples, the measurement of mechanical properties was done. The

use of short bamboo fiber improved mechanical properties, while the use of hollow glass microspheres controlled the increase in the density of the short bamboo fibre addition [7].

The reinforcement of PP with talc or short glass fibre had in one study the same influence on the creep deformation, respectively did not change the creep mechanism significantly. The creep strength was improved in comparison to the pure PP [8]. Next possible filler for reinforcement to obtain better mechanical properties of PP are multi-walled carbon nanotubes. Hui Zhang and Zhong Zhang created multi-walled carbon nanotubes/polypropylene composites which compounded using a twin-screw extruder. The nanotubes had different lengths of 1-2 μm and 5-15 μm and similar diameter of 10-30 nm. The nanotubes were applied at a constant volume content of 1 %. After testing, they found out that both longer and shorter nanotubes can improve the impact energy of PP matrix at temperatures above glass transition temperature. The greater effect for improvement of the impact energy the longer nanotubes had in comparison to shorter ones [9].

The combination of PP, polyamide 66, molybdenum disulphide, silicon carbide and alumina was investigated. The scientists found that the addition of micro fillers had the hybrid effect on mechanical properties of this blend. The tensile strength and strain were decreased due to the hybrid effect of fillers above-mentioned. The flexural strength at first decreased but increased after the addition of micro fillers. The improvement of hardness and the density was found out. The improvement of the fracture toughness around 188 % was noticed after using these micro fillers [10].

Many research papers concentrating on the impact behaviour of PP have been written, but not so many

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scientists used for these articles the drop-weight impact test. This study is focused on the impact behaviour of pure and glass fibre reinforced PP. The multi-axial behaviour of both polypropylenes was tested on drop-weight impact test machine at different set potential energies. The results were subsequently discussed and evaluated. It was found out that pure PP is more suitable material for more demanding application to the impact loading.

2 Experimental

Virgin and reinforced Polypropylene with 30 % of glass fibre were used as the basic polymer materials (TATREN, IM 25-75 and Scolefin 53 G 10) [11]. An ARBURG Allrounder 470H Advance Injection moulding machine was used for sample preparation, with the processing conditional on complying with polypropylene (PP and PP30GF) producer's recommendations, as can be seen in Tab. 1. The samples were in the shape of plates with dimensions 100×100×3 mm according to ISO 6603-2.

Injection moulded PP, and PP30GF samples were tested on drop-weight impact test machine Zwick HIT230F according to ISO 6603-2 at the ambient temperature of 23 °C. The scheme of this arrangement is possible to see in Figure 1. As the main parameter was used potential energy, which was set on the testing machine. 15 samples at each set potential energy (30, 50, 100, 150, 200 and 230 J) were tested and then maximum impact force was statistically evaluated in program TestExpert II, MS Excel 2016 and MiniTab 16. At the end of the test, crack surface was evaluated at each potential energy.

Table 1: PP and PP30GF set injection moulding parameters.

Injection Parameters	Values	
	PP	PP 30 % GF
Injection Pressure [MPa]	70	80
Injection velocity [mm.s ⁻¹]	40	50
Holding Pressure [MPa]	55	60
Cooling Time [s]	25	20
Mould Temperature [°C]	30	40
Melt Temperature [°C]	215	235

3 Results and discussion

This study is concentrated on the multi-axial behaviour of virgin and reinforced polypropylene with 30 % of glass fibre by drop-weight impact test. Injection moulded PP and PP30GF parts were tested on penetration where set potential energy in the range from 30 to 230 J and the results were subsequently evaluated.

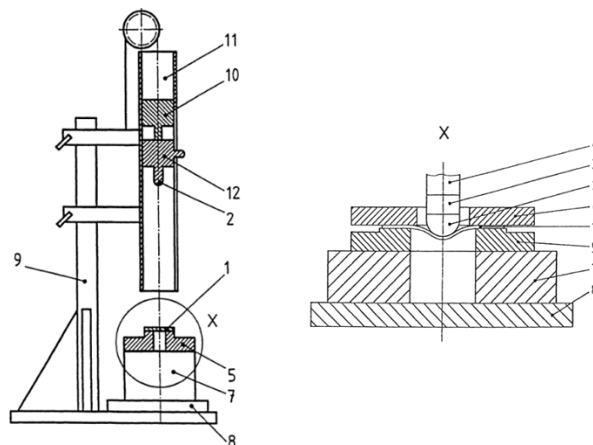


Fig. 1. Drop-weight impact test scheme.

1 – Test specimen; 2 – Hemispherical striker tip 10 mm; 3 – Force sensor; 4 – Shaft; 5 – Test specimen support; 6 – Clamping ring (optional); 7 – Base; 8 – Acoustic isolation (optional); 9 – Stand for falling-dart system; 10 – Holding and release system for weighted striker; 11 – Guide shaft for weighted striker; 12 – Weighted striker 23,77 kg.

3.1. Maximum impact force

PP30GF statistical evaluation of the measurements is shown in Table 2. This article is continuing of the last study about PP optimization of fall height [8]. Therefore, changes in virgin and reinforced polypropylene can be evaluated by penetration test (multi-axial loading).

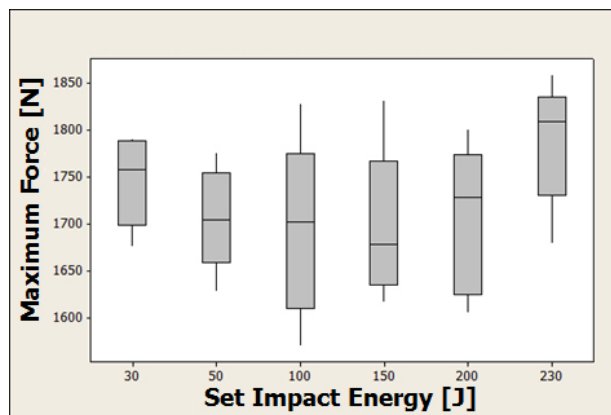


Fig. 2. PP30GF Boxplot graph of maximum force at set potential energy.

In Figure 2 the PP30GF maximum force at set potential energy is displayed. Measurements are burdened with a high error because of a non-defined arrangement of glass fibres. Therefore, the median was chosen to compare the maximum force values. PP30GF value median at 30 J 1758 N was evaluated, with increasing set potential energy value of maximum impact force is slightly decreasing up to 150 J. Another increase in set potential energy has led to a rapid rise in maximum force on value 1808 N at 230 J. However, the differences of the measured values are within the error measurement range.

The PP and PP30GF maximum impact force change in % can be seen in Figure 3. The changes move in 17 % from the PP sample with no penetration to last

Table 2. PP 30 % GF maximum force statistical evaluation at the set potential energy.

Set energy of fall [J]	30	50	100	150	200	230
Statistical characteristics [N]						
Number of measurements	15	15	15	15	15	15
Arithmetic mean	1744	1704	1698	1701	1705	1789
Type error A	14	16	29	24	24	19
Standard deviation	44	50	93	75	75	60
Minimum value	1676	1629	1571	1617	1606	1679
Median	1758	1704	1702	1678	1728	1808
Maximum value	1790	1776	1828	1831	1800	1858
Variation range	115	147	257	214	194	179

penetrated PP sample. The change of maximum impact force for PP30GF is negligible as described above. It is possible to see double times higher value of maximum impact force for PP in comparison with PP30GF. This is caused by non-defined arrangement of glass fibre, resulting from processing technology – injection moulding.

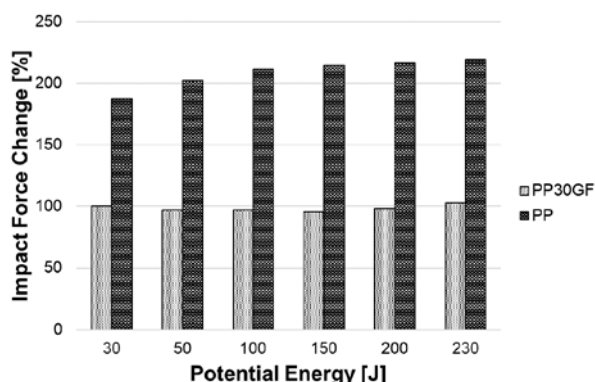


Fig. 3. PP30GF, and PP percentage change in maximum force to the prescribed base potential energy of 30 J.

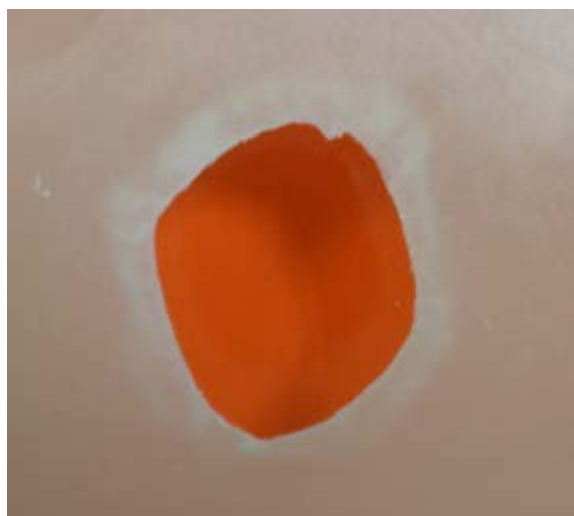


Fig. 4. PP30GF deformation after drop-weight impact test at 30 J.

3.2. Deformation after the test

After the drop-weight impact test the tested parts were photographed for better idea about the deformation, and crack growth.

In Figure can be seen deformation of PP30GF at 30 J. Through the penetration of the penetrator, sharp edges of the hole are formed. On the other hand, in Figure 5 it is shown that the PP at 30 J was not penetrated because of too small set potential energy which is needed for penetration. There is seen just plastic deformation of the PP material.



Fig. 5. PP deformation after drop-weight impact test at 30 J.

The set potential energy of 50 J causes both PP30GF and PP to penetrate. In Figure 6, for PP30GF, a larger hole can be seen than the diameter of the penetrator, the material is splintered from the center to the edges. In Figure 7, in the case of PP, the material encircles the penetrator, large plastic strains can be observed. A similar trend is observed at set potential energy 230 J for both materials PP30GF (Figure 8), and PP (Figure 9) in comparison with deformation at 100 J.

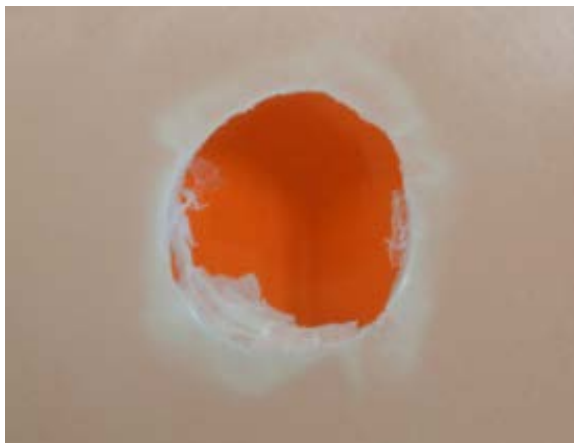


Fig. 6. PP30GF deformation after drop-weight impact test at 100 J.



Fig. 7. PP deformation after drop-weight impact test at 100 J.

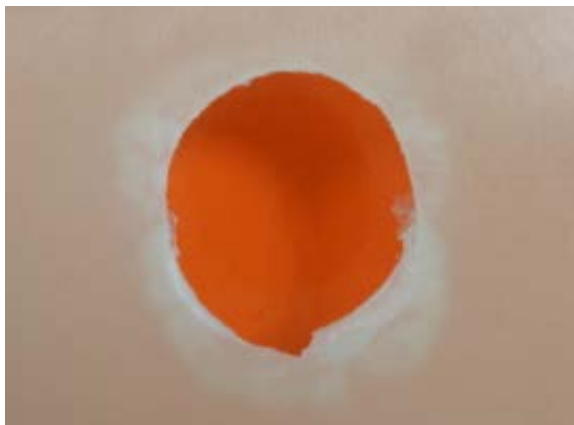


Fig. 8. PP30GF deformation after drop-weight impact test at 230 J.

4 Summary

In this study the injection moulded PP30GF, and PP parts were subjected to the drop-weight impact test at a different set of potential energies. The range of potential energies was from 30 to 230 J. Set potential energy does not affect the maximum impact force of both materials (PP30GF, and PP), but changes the character of the deformation. Maximum impact force, in case of PP, is twice as large as PP30GF value. This difference can be

caused by the higher fragility of PP30GF caused by added glass fibres. It can be stated that for the application where the impact loading is often used, pure PP is more suitable material. In this way it is possible to test much higher amount of polymeric materials for the better knowledge of the material behavior issue.



Fig. 9. PP deformation after-drop weight impact test at 230 J.

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