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INFLUENCE OF IRON-BASED POWDER ADDITIVE ON A SHAPE ACCURACY OF INJECTION MOULDED PARTS

Patrik DOBROVSZKÝ[1], Jozef BÍLIK[1], Ján MILDE[1],
Michaela KRITIKOS[1], Libor ĎURIŠKA[1]

[1]SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA
INSTITUTE OF PRODUCTION TECHNOLOGIES
ULICA JÁNA BOTTU 2781/25, 917 24 TRNAVA, SLOVAK REPUBLIC
patrik.dobrovszky@stuba.sk, jozef.bilik@stuba.sk, jan.milde@stuba.sk,
michaela.kritikos@stuba.sk, libor.duriska@stuba.sk
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Abstract

This paper reviews the effects of iron-based powder on shape accuracy of injection moulded parts. Analysed specimens were produced on a micro injection moulding machine. At first, specimens of pure polypropylene (PP) were manufactured. Then specimens containing 1, 2 and 3 vol. % of iron powder additive were produced using the same process parameters. Subsequently, the samples were scanned using scanned using Zeiss METROTOM CT scanner. Results were analysed via CAE inspection tools. The main aim was to compare the shape and flatness of the scanned specimens to the nominal models. Results showed that iron-based additives of this vol.% had no significant effect on shape accuracy of produced parts. This paper is a partial result of the ongoing research focused on effect of iron and steel-based additives on material, magnetic and mechanical properties of polymers.

Keywords

Composite, polypropylene, injection moulding, powders

INTRODUCTION

Industry produces a wide range of polymers. Materials with higher processing and functional qualities are frequently required, however. Polymer composites occupy a unique position among the materials experiencing the most rapid expansion in the plastics sector. These materials are widely used in a variety of industries, including automotive, construction, packaging, and other applications [1, 2].

To achieve unique features, composite materials combine two or more components. Thermoplastics and thermoset plastics are utilized as matrix and fibres in many novel composites, with powdered metals or ceramics functioning as reinforcement [3].

Several authors have studied the influence of metal powders on polypropylene. Güldas et al. [2] studied mechanical properties of aluminium powder filled PP. Their research showed that tensile strength values decreased depending on the increase of reinforcement size and reinforcement rate, and Izod Charpy values increased with higher reinforcement rate. PVC filled with aluminium powder was studied by Bishay et al. [4]. Their research showed that the mechanical strength values decrease with increasing the Al content and also that the presence of Al powder enhanced the thermal stability of the PVC composites. In the case of a polyester resin reinforced with Al or Cu particles, it was shown that at 15 % by volume of the reinforcing component, the tensile strength increased from ~50 MPa to ~95 MPa. At the same time, the impact toughness (Izod test) decreased when the condition that the composite contained more than 5 % by volume of the reinforcing component was met [5].

Taşdemır et al. [5] studied polymer composites with 5, 10 and 15 vol. % Fe powder, where the matrix was of three different polymers, namely high-density polyethylene (HDPE), polypropylene (PP) and polystyrene (PS). When increasing the amount of reinforcing component led to the increased resulting hardness of the composite, but decreased the impact toughness in the Izod test, as in the previous publication. In the case of the HDPE matrix, the effect of Fe powder was most pronounced with an increase in hardness at as little as 5 vol. % Fe. When increasing the volume fraction of the reinforcing component to 10 and 15 %, the increase in hardness was only minimal. The impact toughness decreased by more than 50 % at 15 % Fe by volume. The effect of the reinforcing component on the PP or PS matrix was minimal [3]. In general, it can be concluded that the addition of metal powders to polymer materials significantly affects the resulting properties and structure of the composite. The addition of aluminium or brass powder increases electrical conductivity, nickel powder increases impact resistance, the addition of copper increases thermal stability [6]. The combination of metallic and polymeric materials yields several advantages. The obtained products are characterized by simpler construction and reduced weight, which leads to higher efficiency and lower costs [7]. As can be seen, some research into composites of polymers and metal powders has already been conducted, however most of the research was aimed at the mechanical properties of produced parts while very little or none at the effect of fillers on shape accuracy of produced parts.

MATERIALS AND METHODOLOGY OF EXPERIMENT

In this study, composite of polypropylene and iron powder were produced by using commercially available products. Polypropylene used in this study was Sabic 576p manufactured by SABIC (Saudi Basic Industries Corporation), material data of this polypropylene can be seen in Table 1 [8].

Table 1 Material data of Sabic 576p [8]

Property	**Value**	**Unit**
Density	905	kg/m³
Melt Flow Rate (MFR) at 230 °C and 2.16 kg	19	dg/min
Tensile modulus	1800	MPa
Tensile stress at yield	37	MPa
Tensile strain at yield	9	%
Hardness Shore D	71	-
Heat deflection temperature at 1.80 MPa (HDT/A)	60	°C
Heat deflection temperature at 0.45 MPa (HDT/B)	90	°C

Iron powder used in this study was ASC 100.29 made of 99.9 % iron, supplied by Höganäs (Sweden), material data of this iron powder can be seen in Table 2 [9].

Table 2 Material data of ASC 100.29 [9]			
Property	**Value**	**Unit**	
Apparent density	2980	kg/m³	
Flow	25	sec/50g	
Chemical analysis, %			
Carbon	<0.01		
O-tot	0.08		
Green strength, MPa			
Compacting Pressure	Lubricated die	0.6 % Kenolube	0.8 % Zn-st
400 MPa	21	14	9
600 MPa	34	21	14
800 MPa	50	24	16

Reinforced polypropylene was produced using three reinforcement rates (1, 2, 3 vol. %). The low volume percentages of the powder were used for reasons outgoing from former (unpublished) results. The most significant reason is the tensile strength which slightly decreases even at low powder volumes. However, such strength is still sufficient for possible applications, which are expected to be based mainly on electrical and magnetic properties. At higher powder volumes, a significant decrease in strength is thus expected. Powder was passed through sieves to ensure particle size was in the desired range up to 40 μm. Polypropylene was then mechanically mixed with the metal powder in separate containers. The produced blend was then mixed, melted and extruded via the extruder of Babyplast micro injection moulding machine at 200 °C. The resulting composite was then ground in an industrial grinder which was disassembled and cleaned before experiments to ensure no contamination. This way, a mixture of polypropylene and metal filler powder was produced. This mixture was then fed into hopper of Babyplast micro injection moulding machine on which tensile strength specimens were produced. This microinjection moulding machine used in this study is produced by CRONOPLAST, Spanish Company. Machine in its current configuration, while having piston diameter of 10 mm installed, is capable of producing clamp force up to 62.5 kN and injection pressure up to 260 MPa. The maximum injected volume is 4 cm^3. The mould which was used for producing the specimens can be seen in Figure 1. Specimens made of clear Polypropylene with no fillers were also produced. Parameters of the moulding process can be seen in Table 3. The manufactured specimens were then scanned via CT Scanner Metrotom 1500 by Carl Zeiss Industrielle Messtechnik GmbH as seen in Figure 2. The scans were inspected in GOM Inspect software. The values inspected were flatness of face of the specimen that was facing ejector pins, and average shape deviation, i.e. warping of the specimen. All process parameters during producing the parts were unchanged; the only variable was the different vol. % of powder in the mixture in each series.

Table 3 Process parameters of injection moulding

Parameter	**Value**	**Unit**
Plastification temperature	200	°C
Chamber temperature	200	°C
Nozzle temperature	200	°C
Injection pressure	160	MPa
Packing pressure	100	MPa
Clamping force	30	kN
Cooling time	10	s
Injection / packing switch over time	2	s

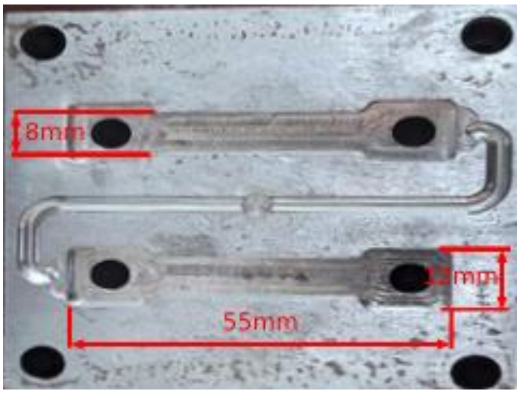

Fig. 1 *Cavity of used mould*

Fig. 2 *Zeiss METROTOM 1500*

RESULTS

Each series of the manufactured specimens were scanned, and actual mesh models were obtained. Mesh models were compared to the nominal CAD model. This comparison was carried out in GOM Inspect software in which the surface comparison was conducted on a nominal CAD model on which a scanned meshes were aligned and deviations from actual model were measured. This surface comparison can be interpreted as a colour map of deviations. Surface comparisons were carried out to evaluate the values of warping on the scanned models. The comparison provided the average value of warping for each series.

Flatness values were analysed at the face of specimen facing ejection holes in the mould. Colour map of deviations during surface comparison of specimen containing 1 vol. % as an example can be seen in Figure 3.

Results from CT scanner showed that there were no significant deviations in the values of shape accuracy with increasing amount of filler. Specimens from all of the series exhibited similar values of warping, and warping occurred in the same regions as in the specimens manufactured of clean polypropylene. Average value of warping in pure polypropylene specimens was 0.09 mm, and flatness value of face facing mould was 0.70. Average value of warping in the specimens containing 1 vol. % was 0.11 mm, while flatness value of face facing mould was 0.49. Average value of warping in the specimens containing 2 vol. % was 0.06 mm, while flatness value of face facing mould was 0.71. Average value of warping in the specimens containing 3 vol % was 0.08 mm, while flatness value of face facing mould was 0.55. In all three series, the shape deviations in specimens reached the values up to 0.3 mm. The biggest deviations were observed in the edge regions of specimens. Shrinkage of specimens was not affected by filler; average length of the produced samples was 54.9 mm in comparison to 55 mm of the nominal model. That means the shrinkage less than 0.5 % in X direction. Average value of warping can be seen in graph in Figure 4, and average flatness values can be seen in Figure 5.

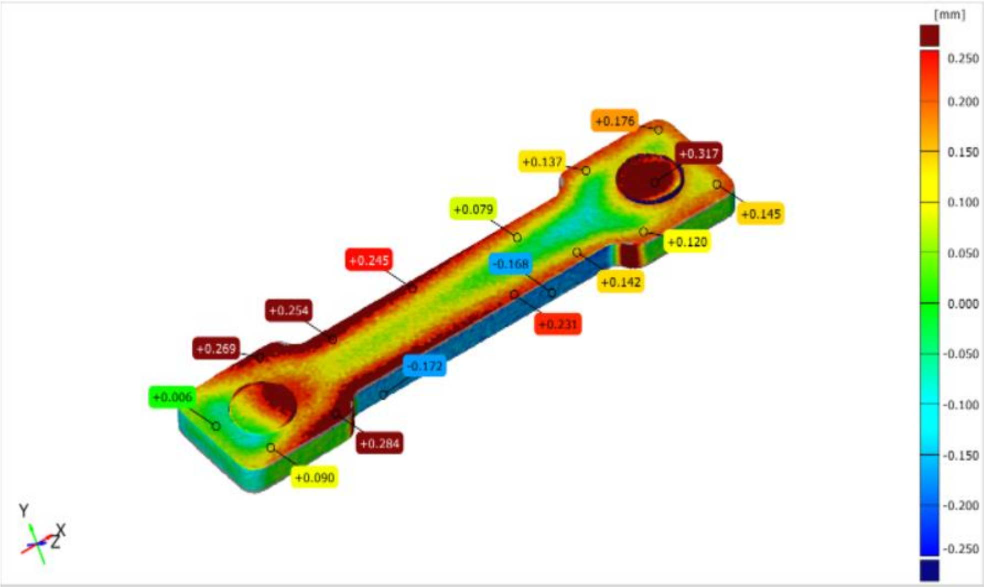

Fig. 3 *Colour map of deviations*

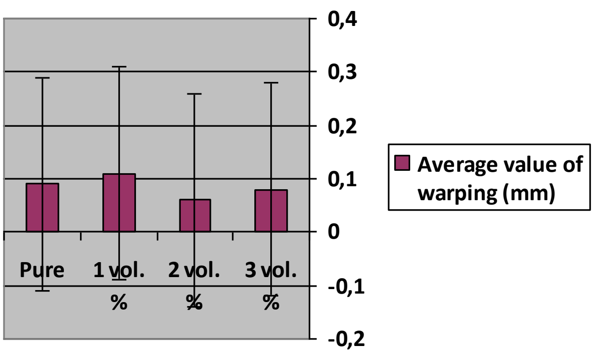

Fig. 4 *Average value of warping*

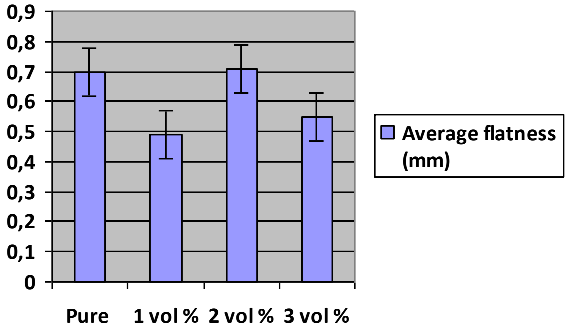

Fig. 5 *Average measured flatness*

DISCUSSION AND CONCLUSION

Shape deviation values and flatness of specimens produced of polypropylene filled with different vol. % of iron powder were inspected. Specimens of unfilled polypropylene were produced as a reference. Any significant changes neither in flatness nor in shape deviation were observed in the specimens containing filler, when compared to specimens not containing filler. It is known, that glass fibre fillers can intensify warpage of produced parts [10]. Therefore, some effect of iron powder filler was expected. It is also known that adding metal additives into polymers have effect on the mechanical properties of produced parts, such as reduced Izod impact strength and increased hardness [3]. Most of the already conducted research has been conducted with higher vol. %, such as 5, 10 and 15 vol. % [3, 5]. It was also studied that, at higher than 5 vol. % of filler, strength and elasticity of material decreased [5]. Therefore, it is still possible, that at higher vol. %, there will be some effect on a shrinkage and warpage. One notable effect the iron powder had was increased temperature of nozzle during injecting into mould, and therefore cooling rate of the machine had to be adjusted in order to retain desired conditions and avoid polymer degradation due to too the high temperature. The shape deviations that were achieved on specimens after cooling may be prevented with increasing packing time and or packing pressure, however for this research it was desired to not alter process parameters in order to eliminate other possible factors causing different rate of shrinkage and warpage. This analysis is just minor part of a bigger ongoing research that is focused on a study of thermal, mechanical, electric and magnetic properties of polymers filled with iron and steel-based powders.

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ORCID

Patrik Dobrovszký	0000 0003-2763-3206
Jozef Bílik	0000-0001-7828-8583
Ján Milde	0000-0002-4804-4665
Michaela Kritikos	0000-0001-5406-3953
Libor Ďuriška	0000-0002-5777-7166