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Microstructure and mechanical properties of Polypropylene/ Polycarbonate blends

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Materials

ABSTRACT

Purpose: Researches, which are presented in this paper, consider the effect of chosen different weight ratios polycarbonate blended in a polypropylene matrix (PP/PC) at variable injection moulding conditions and its effect on the microstructure, and also on fracture and flexural properties.
Design/methodology/approach: Composites contain between 0 and 30 wt % of polycarbonate and changes at constant rate of 10wt%. Specimens were produced with advantage of melt manipulation technology, further called as non-conventional injection moulding technique (SCORIM). Then, the results were compared with conventional injection moulding, as a result of comparison structure development and mechanical behaviour. Fracture and flexural tests were done on universal testing machine - Instron. The structure sample appearance was observed in polarized light microscope.
Findings: PC addition influence on energy absorption and flexural modulus. There are also visible microstructure changes. The SCORIM technique have a significant influence on mechanical properties. Higher settings of those processing variables give higher values of energy at break and flexural modulus.
Research limitations/implications: Further work contains research of termomechanical indices to establish straightforward connection between mechanical properties and processing set-ups. Other mechanical properties will be assessed.
Practical implications: The improvement of mechanical response is clearly visible by using SCORIM technique and increasing a percentage polycarbonate volume.
Originality/value: The Shear Controlled Injection Moulding technique is based on the in-mould shear melt manipulation during the solidification phase. This technology is very important for morphology manipulation and the improvement on the mechanical polymer system properties.
Keywords: Engineering polymers; Polypropylene; Polycarbonate; SCORIM; Non-conventional injection moulding

1. Introduction

Polymer blends have drawn great attention in scientific research and industrial production. Polypropylene (PP) is a low-cost polymer with versatile applications but with limited impact strength. In recent years, polymeric composites were widely used in the production of new engineering materials. It is perceived as a reflection of technological development. Meanwhile the polymeric composites are promising, due to their economic versatile applicability and good mechanical properties[1-4,15]. Due to the increasing demand for polymers, these materials bring new problems. A frequent goal of polymeric material research is the improvement of physical properties [5,7]. An approach that is widely used the combination of two polymers in the hope of obtaining favorable properties in the blend [6,8].

Structures and properties of products made of immiscible polymer blends reinforced plastics are more strongly affected by processing than those of simples, single phase polymers. Flow in the machinery and in the mold affects the shape, size, as well as the orientation of the dispersed phase in the matrix. This leads to a flow induced anisotropy in mechanical and other physical properties [9-12] .

One of the most popular commercial technique for manufacturing polymers is injection moulding. Many processing variables play an important role during forming technique, determining the product morphology and properties [13-14].

In this study shear controlled orientation technique in injection moulding has been used to improve the mechanical properties of PP/PC composites.

2. Materials and methods

2.1. Materials

The polymers used in this work are listed in table 1. Specimens were produce with advantage of melt manipulation technology called further as non-conventional injection moulding technique (SCORIM). Before mixing, the polycarbonate (PC) was dried at 120°C during 4 hours (as recommended by the material supplier) in a dehumidifier (dew point of -40°C).

Table 1.
Materials used in the experiments

Type		Density [g/cm^3]	Melt temp. [°C]
PP	*Moplen HP501M*	0.9	200
PC	*Lexan 123R PC*	1.2	240°C

Mixing of the blends has been done in a rotational drum at the rotor speed of 60 rpm and at room temperature. After mixed, blends were direct injection moulded.

2.2. Processing

In the work two types of injection moulding techniques have been used:

a) melt manipulation injection moulding technique, (SCORIM);
b) conventional injection moulding, for comparison purpose (CIM).

All composites were injection moulded into rectangular bar with the following dimensions: 130mm x 12mm x 8mm, by using a Ferromatik Milacron injection moulding machine type K85. Pressure of two pistons of the SCORIM device was controlled by external hydraulic system from Allen Bradley UK, with a maximum pressure of 150 bar per cylinder . All specimens were moulded on stabilized processing condition. Composites constitution is presented in table 2.

Table 2.
Investigated polymers and its weight blending ratio

Polypropylene [wt%]	Polycarbonate [wt%]	Composites description
100	0	Neat PP
90	10	PP/PC 10
80	20	PP/PC 20
70	30	PP/PC 30

The following processing variables were selected as of interest for the investigation: melt temperature, T_p, stroke time, S_t and stroke number, S_n. Table 3 presents details of processing steps.

Table 3.
Moulding programme for rectangular specimens

Run	Melt temp. [°C]	Stroke time [s]	Stroke number
1	240	1	3
2	240	3	12
3	280	1	3
4	280	3	12
5	240	Conventional injection moulding	
6	280		

All the other processing parameters were kept constant (Table 4).

Table 4.
Constant injection processing set-up (machine readings)

Injection velocity	10mm/s
Injection pressure	150bar
Holding pressure	50bar
Mold temperature	30°C
Cooling time	30s

2.3. Preparation for optical observation

The microstructure of the mouldings was characterized on an Olympus polarized light optical microscopy (PLM) type BH-2 additionally equipped by the Olympus digital camera type DFC280. Thin slices with 20μm of thickness have been performed on the cut machine Microtome Anglia type 200 from the mid-length of the mouldings, perpendicularly to the flow direction.

2.4. Preparation for mechanical tests

A fracture test was performed in an Instron universal testing machine type 4505 with cross-head velocity of 10mm/min (according to the ASTM E399 standard) at 23°C and 55% of humidity. A three point bending support was used in a SENB mode (Single Edge Notched Bar). The moulded bars were notched in its middle length with depth of 6.35mm in a Ceast cutting notch machine type 6816 with the blade radius 0.47mm.
Before testing each notch was additionally sharpened by sliding with a fresh razor blade. A flexural test was performed in an Instron with cross-head velocity of 2.8mm/min (according to the ISO-178-75 standard). At least five specimens have been analyzed for each test.

3. Results and discussion

3.1. Microstructure characterisation

Figures 1 show the polarized light micrographs of the SCORIM and CIM specimens of the polymer composites. All conditions feature a well defined skin-core structure: a central core surrounded by external layers of the oriented material. In Fig. 1, the mouldings obtained with the first condition (R1) exhibit thicker and less numerous layers.
These mouldings were produced with the lower melt temperature (Table 3) and lower S_t and S_n. Runs 4 feature the thicker highly oriented external layers obtained under highest S_t and S_n parameters at high moulding temperature. These runs presents well expanded multilayered region.

3.2. Mechanical characterisation

Fracture behaviour is diversified between neat PP and PP/PC 30 systems. Increment of volume content of PC causes decrement of energy at break. For the neat PP and PP/PC 10 moulded in higher temperature causes decrement of energy at break. In opposite way is for PP/PC 20 and PP/PC 30. Increment a melt temperature causes increment of energy.

Figure 2 and 3 presents flexural modulus and energy at break for all of the composites moulded by SCORIM and CIM techniques. Based on flexural test was found that increment of T_m in PP/PC 20 and PP/PC 30 composites causes increment of modulus values. Reverse behaviour present neat PP and PP/PC 10, where increment of T_m parameter causes a decrement of flexural modulus.

The differences between energy to break point and modulus for all of the material systems are presents in Table 5. To summarize that table can be noted that the highest values of energy at break comes from neat PP moulded by SCORIM technique. Increment a wt % of PC causes increment of flexural modulus and decrement of energy at break.

It was found that the materials moulded in higher process set-up of SCORIM causes increment of flexural modulus value . The increase of flexural modulus is caused by more number oriented layers obtained in high SCORIM settings as a result of the high stress field and cooling rates imposed during the processing stage.

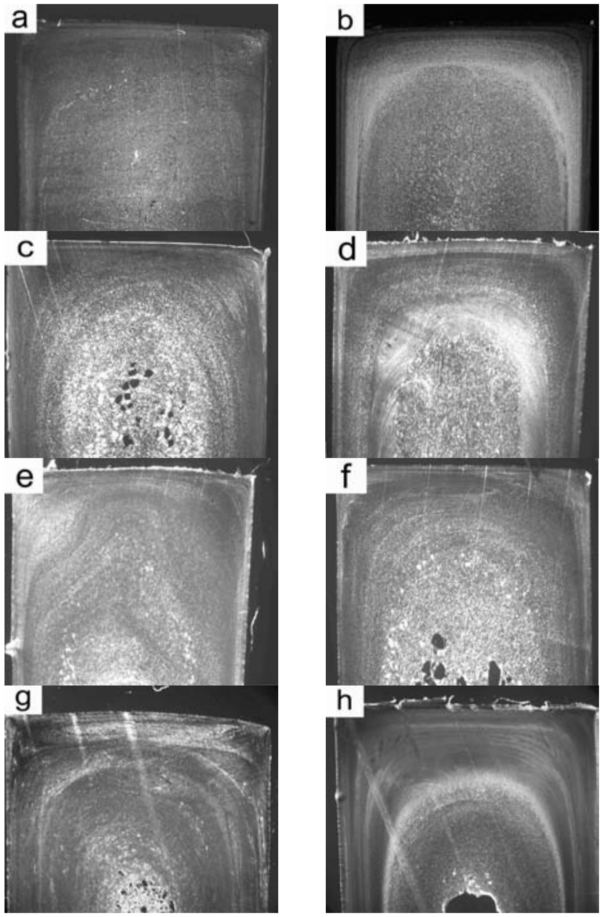

Fig. 1. Polarized light micrographs of PP composites: (a) neat PP, Run 1, (b) neat PP, Run 4, (c) PP/PC 10, Run 1, (d) PP/PC 10, Run 4, (e) PP/PC 20, Run 1, (f) PP/PC 20, Run 4Polarized light micrographs of PP composites: (g) PP/PC 30, Run 1, (h) PP/PC 30 Run 4

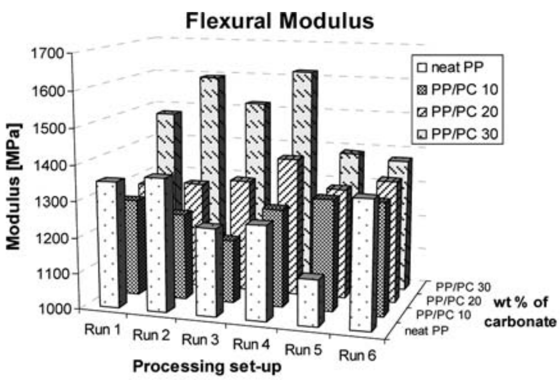

Fig. 2. Flexural modulus of the composites for all of the runs

Table 5.
Mechanical characterization of the blends

	Neat PP		PP/PC 10		PP/PC 20		PP/PC 30	
Run	Energy at break [J]	Modulus [MPa]	Energy at break [J]	Modulus [MPa]	Energy at break [J]	Modulus [MPa]	Energy at break [J]	Modulus [MPa]
1	0.33	1351	0.72	1271	0.37	1289	0.25	1479
2	0.59	1370	0.56	1242	0.37	1299	0.2	1593
3	0.23	1244	0.63	1178	0.41	1317	0.33	1520
4	0.43	1263	0.54	1274	0.41	1388	0.23	1618
5	0.53	1128	0.41	1311	0.33	1310	0.3	1387
6	0.37	1352	0.33	1313	0.39	1342	0.34	1374

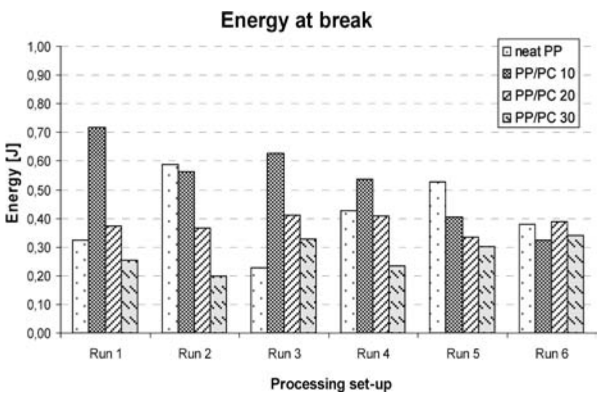

Fig. 3. Energy at break of the composites for all of the runs

4. Conclusions

- The microstructure of SCORIM mouldings materials is strongly depend upon the processing conditions and materials.
- Immiscible polymer blends PP/PC processed by melt manipulation techniques show improved modulus compared to neat PP.
- SCORIM settings and melt temperature are determinant of energy at break and flexural modulus.
- The addition of PC to PP matrix significantly changed the morphology and mechanical properties of composites.

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