Glass fibre contents of PP plates and their properties: Part I: Shrinkage and changes in time

A. J. Pontes, N. M. Neves, J. C. Velosa, A. R. Faria, A. S. Pouzada

Department of Polymer Engineering, Universidade do Minho,

Campus de Azurem, 4800-058 Guimarães, Portugal

Keywords: Injection Moulding, Short Glass fibres Materials, Shrinkage.

Abstract. In this paper the results from the first part of a study on the glass fibre contents of PP plates and their properties is presented. Focus is made on the effect of the fibre volume fraction and holding pressure on the experimental as-moulded shrinkage in the flow and across flow directions. Data is also presented on the post-moulding shrinkage. For the experimental work, PP with different volume fraction of glass fibre (0, 0.1, 0.2 and 0.25) was used. The mouldings are edge gated flat rectangular plates. The moulding process was continuously monitored with pressure transducers.

Introduction

Short fibre reinforced polypropylene compounds are used to produce composites taking advantage of their interesting properties and competitive prices. For the same reason short glass fibres are the most used reinforcement in injection moulded thermoplastic composites.

Using mass production techniques (e.g. injection moulding) and reinforced polymers it is possible to produce inexpensive complex geometry composite products with stiffness properties superior to those of unreinforced polymer products. However, to manufacture products with high specifications in terms of dimensional accuracy and stability, knowledge is required on how processing variables, the mechanical and flow properties of the polymer and its geometry will influence the final properties of the product.

Progress was made for accurately predicting shrinkage in injection moulded products. In spite of the progress made to predict the final dimensions of injection-moulded parts is still a challenge.

Part shrinkage is a geometric modification (can be a reduction or an expansion) in the size of the part. The driving force of shrinkage is the volumetric changes of the material as it cools from the melt state to solid. Despite the apparent simplicity of this statement, the relationship between volumetric shrinkage and the linear shrinkage of the component is affected by mechanical properties, mould constraint [1] and orientation effects.

The fibre reinforced composite materials show lower as-moulded shrinkage compared with unfilled material, because the fibres have much lower thermal expansion coefficients than the matrix polymer, therefore diluting the effects of the shrinkage of the polymer.

It is well known that the shrinkage is lower in the fibre direction and larger in the transverse directions [2,3]. Henceforth the mould designer must be able to predict the shrinkage in the various directions if dimensional accuracy is required for the mouldings.

In fibre composite materials the shrinkage variation results mainly from the anisotropy of the polymeric matrix and the fibre orientation field. Processing conditions and the fibre contents (due to the fibre-fibre interaction), influence the fibre orientation distribution. The prediction of the composite shrinkage depends on the accuracy of the prediction of the orientation field.

A further change in the dimensions of the moulding may occur over an extended period of time (days or even months) this being so even if the moulding is kept at modest temperatures. This results from changes in density deriving from post-moulded phenomena such as secondary crystallization [4].

In this paper the glass fibre content level effect is analysed and, the shrinkage and its changes with time of injection moulded rectangular PP plates.

Materials and Methods

All experiments were performed with a unfilled polypropylene homopolymer with MFI 15 (210ºC, 21.6 N) from Odebrecht (OPP-PH306). The granules with different fibre fractions (0.1, 0.2 and 0.25) were obtained by mixing chopped fibres and the unfilled polypropylene in a twin screw extruder.

The moulding programme use a cell consisting of a Krauss Maffei KM60/210A injection moulding machine of 600 kN clamp force and a thermal regulator, Klöckner Ferromatic Desma – T10EW403.

The mouldings, edge gated rectangular plates, have the main dimensions of 150x40x2 mm^3. The gate thickness and length are 1.5 mm and 0.7 mm, respectively. Three pressure sensors were located along the flow path: in the nozzle (P0) and in the cavity at 40 (P1) and 110 mm (P2) downstream from the gate (figure 1). All signals were recorded with a Kistler data acquisition system.

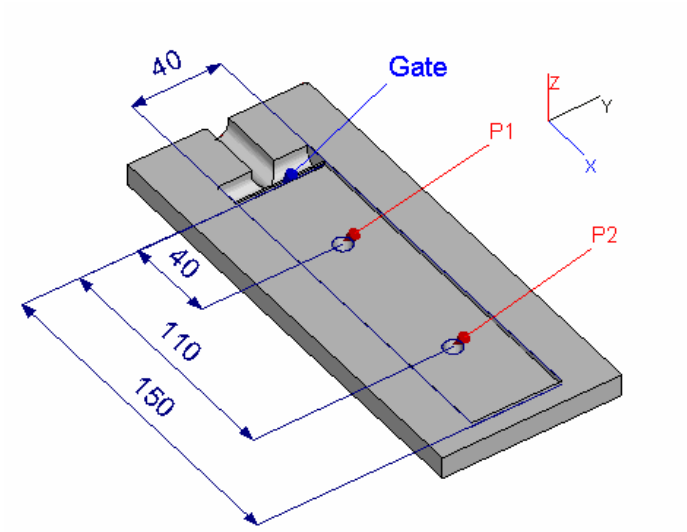


Fig. 1 - Cavity with pressure transducer location

All mouldings were produced at an injection flow rate of 27 cm^3/s, mould temperature of 27ºC and injection temperature of 230ºC. The holding stage lasted for 7 s (th) at a constant holding pressure (ph) . The time after holding (cooling time) was kept at 15 s. In order to allow for stabilisation of the process, 10 mouldings were rejected between each set up.

The dimensions of each 5 consecutive mouldings were measured 1 hour after ejection. Then the plates were kept at controlled temperature of 20±1ºC, and measured at approximately 24, 72, 96 and 192 hours after moulding.

The length was measured with a LVDT transducer (precision ±1 µm), the width in P2 and P3 with a digital calliper (precision ±10 µm), and a micrometer (precision ±10 µm) was used to measure thickness. Furthermore, the room temperature was monitored during each measurement in order to minimise dimensional variations due to the thermal expansion of the material.

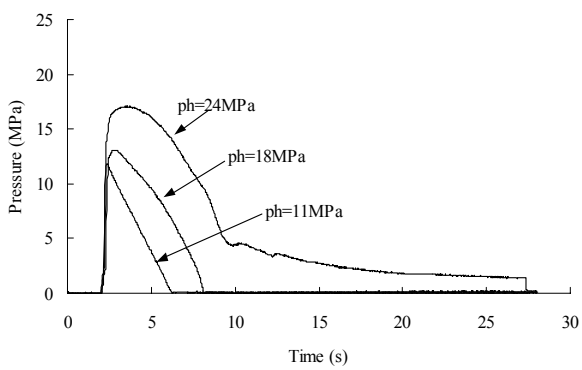
Shrinkage was calculated as $(L_0-L)/L_0$ where L_0 is the original dimension of the mould, and L is the dimension of the sample. The shrinkage was statistically characterised by average and standard deviation.

Results and discussion

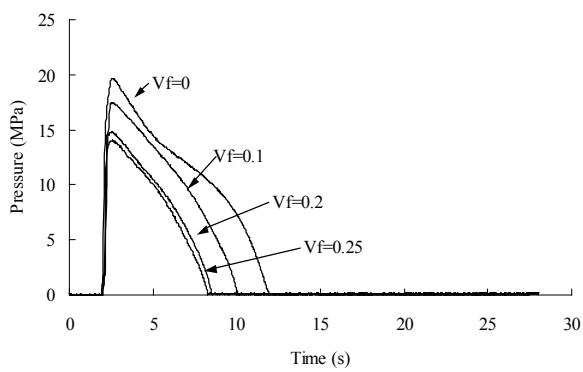
Pressure measurements.

The effects of holding pressures and the fibre volume fraction on the experimental pressure evolution in the cavity at position P2, is shown in figures 2a and 2b, respectively.

It can be seen in figure 2a, that for lower holding pressures, the pressure in the mould cavity becomes zero between 6 and 8 s. For higher holding pressures (ph=24 MPa), the over packing of the polymer in the cavity at the moment of the gate freeze-off is so high that thermal contraction due to cooling is not able to offsett the pressure effect.



a) effect of holding pressure for PP with V_f=0.25



b) effect of fibre volume fraction for ph=18 MPa

Fig. 2 – Measured cavity pressures at transducer P2

In figure 2b it can be observed the effect of fibre volume fraction on the pressure evolution for condition with ph=18 MPa. The pressure in the cavity decreases with increasing fibre volume fraction. This is an expected behaviour because the incorporation of the fibres increases the viscosity leading a more difficult flow during packing.

As-moulded shrinkage

The experimental results of the as-moulded shrinkage in function of the holding pressure for the V_f=0.25 of PP, is shown in figure 3. It can be see upon increasing the holding pressure, the shrinkage in the across flow direction decreases from about 1.5% to 0.8%. However, the shrinkage in the flow direction seems to be not affected by this processing variable.

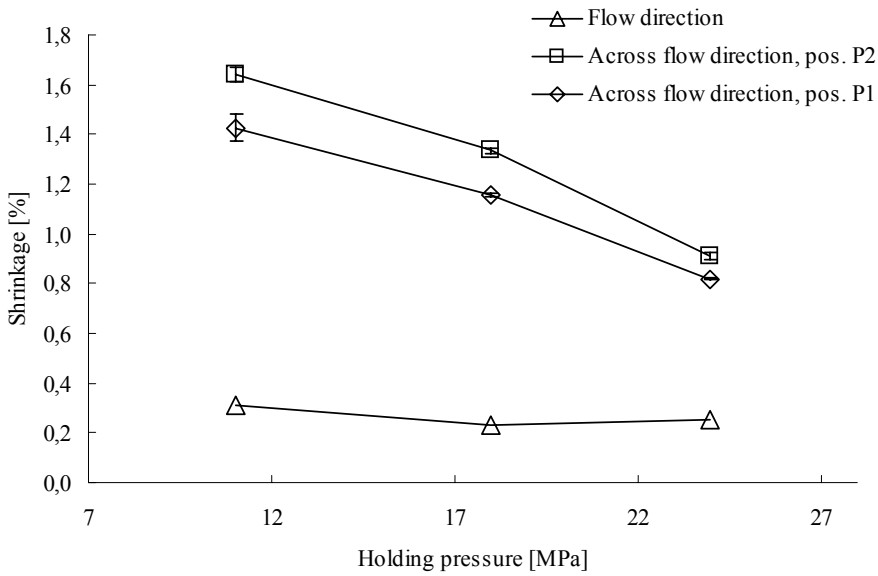


Fig. 3 – As-moulded shrinkage in flow and across flow direction in function of holding pressure PP with V_f =0.25

The effect of the fibre volume fraction (V_f) in the flow and across flow direction for ph=18 MPa, on the shrinkage is shown in figure 4. The addition of short glass fibres has a dramatic effect on the shrinkage and increases the level of anisotropy. The shrinkage in the flow direction drops from about 1.3 % for the unfilled PP to 0.2 % for the V_f=0.25 filled PP. The across flow shrinkage is much less affected by V_f and shows a slight increase with it. The lower pressure reading in position P2 in relation to position P1, explains the slight increase of shrinkage in across flow direction in that position. The slight anisotropy for the unfilled PP is probably due to some differential shrinkage inside the mould [1].

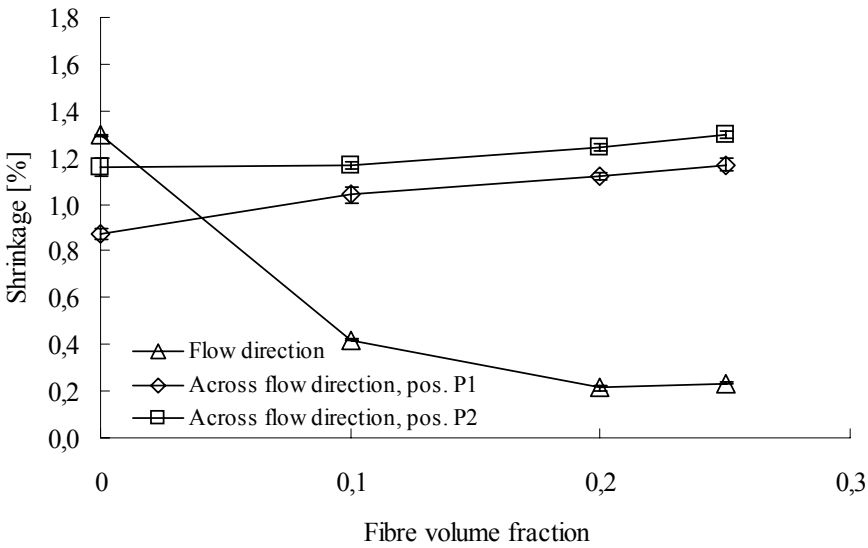


Fig. 4 – As-moulded shrinkage in flow and across flow direction in function of fibre vol. fraction for ph=18 MPa

Post-moulded measurements

The shrinkage changes in time in the flow direction, depends on the fibre volume fraction, as can be seen in figure 5. It can be observed that the shrinkage in flow direction increases linearly with the logarithm of time. The slope of the lines (shrinkage rate) is similar for the different fibre volume fraction.

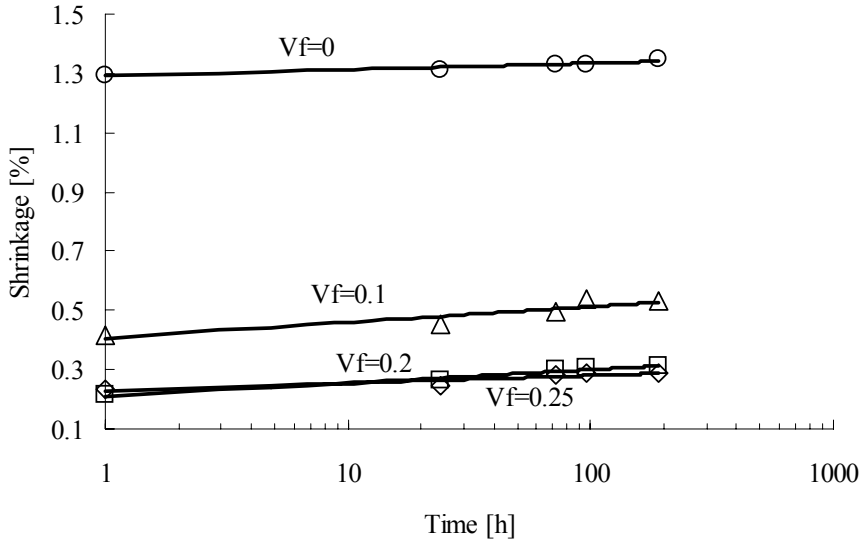


Fig. 5 – Shrinkage changes in time in flow direction in function of fibre vol. fraction for ph=18 MPa

The linear shrinkage rate in the flow direction (x) and across flow direction (y), for different fibre volume fractions is given in table 1. It can be observed that the shrinkage rate decreases with increasing V_f. As an example: a sample of unfilled PP experiences an extra shrinkage across flow direction in position P1, of about 0.2% after 100 hours and a PP filled with V_f=0.25 experiences an extra shrinkage of 0.02% in the same period.
The negative shrinkage in the across direction at position 2 of V_f=.25, is probably due to a measurement error.

Table 1 – Shrinkage rate for different fibre volume fraction with ph=18 MPa

Fibre volume fraction	$\delta x/\delta \log(h)$ [10^{-4}]	$\delta y_1/\delta \log(h)$ [10^{-4}]	$\delta y_2/\delta \log(h)$ [10^{-4}]
0	2	10	5
0.1	5	6	5
0.2	4.5	2	2
0.25	2.6	1	-0.2

Conclusions

The addition of glass fibre in polypropylene decreases substantially the as-moulded and post-moulded shrinkage The as-moulded shrinkage in the flow direction decreases substantially with V_f and is slightly affected in the across flow direction. The pressure evolution in the cavity is also influenced by the addition of fibres due to the increase of material viscosity. The shrinkage decreases upon increasing the holding pressure.

References

[1] A.J. Pontes, R. Pantani, G. Titomanlio, A.S. Pouzada: Intern. Polymer Processing, vol. 15, nº 3 (2000), pp. 284.

[2] K.M.B. Jansen, D.J. Van Dijk, M.H. Husselman: Polymer Eng. Science, vol. 38, nº 5 (1998), pp. 838.

[3] K.M.B. Jansen, D.J. Van Dijk, M.J.A. Freriksen: Polymer Composites, vol. 19, nº 4 (1998), pp. 325.

[4] S.K. De, J.R. White: Short fibre-polymer composites, (Woodhead Publishing Ld, England, 1996).