MICROTESTING OF MICRO-INJECTION MOLDED PARTS

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Abstract *With the growth and demand for microinjection moulded thermoplastic parts becoming ever so popular, an increased need for determination and understanding of material mechanical properties at the micro-scale level is observed [1]. One of the most widespread mechanical characterization experiments is the tensile test. The use of miniaturised tensile apparatus is therefore a need. In this work we developed a novel universal microtesting apparatus for performing mechanical tests in micro-mouldigs. The influence of injection moulding processing conditions on the mechanical behaviour of Polypropylene (PP) and Methyl Methacrylate-Butadiene-Styrene (MABS) microinjection moulded specimens is studied.*

Key Words: *micro-testing apparatus, micro-injection*

I INTRODUCTION

There has been a considerable interest in recent years in microsystem technology, and this is expected to show continuing expansion over the next decade with the trend towards miniaturization of components and increasing application of micro-devices. Analysts predict that microsystem technology will have a farreaching influence on device manufacture in the near future [2]. Since the 1980s, microsystem technology has grown in importance, and it is forecasted to be one of the main technologies of the 21st century [2].

Micro-injection moulding is a mass productive method to produce small polymeric components of tight tolerances and complex geometry. Typically the micro-injection moulded components have a mass of only a few milligrams [3]. Their dimensions are relatively small and in most of the cases the dimensional tolerances are in the micro-scale range. The influence of processing conditions on the properties of micro-mouldings is a topic of ongoing research and of highly scientific and industrial interest [3, 4].

Due to their dimensions, it is obvious that conventional material testing methods (e.g., dynamic mechanical analysis, DMA, and micro-tensile apparatus) cannot be used to fully characterise micro-sized specimens or micro-components. There is therefore a necessity to use special micro testing equipments for the mechanical characterization of miniaturized specimens/components. In this work, a novel miniaturised mechanical tester is presented and used to characterise the tensile behaviour of microinjected parts produced in a polypropylene homopolymer (HPP) and a methyl Methacrylate-Butadiene-Styrene (MABS) and with different settings the machine operative parameters.

II MICROTESTING APPARATUS

Our own developed microtester incorporates some innovative characteristics that distinguish it from available commercial solutions (e.g., MINIMAT from Rheometric Scientific or the microtester produced by EnduraTEC) [5], such as:

- Simultaneous movement of both grips in opposite directions;
- Maximum applicable force of 1000 N;
- Velocity range between 0.1 and 100 mm/min;
- It is a universal testing equipment with the possibility to perform tensile, compression and 3 point bending, as well as linear, sinusoidal and cyclic loadings;
- Due to its reduced dimensions it is possible to use in-situ with a large variety of structural characterization techniques;
- Minimum distance between grips is bigger than 0 mm; maximum distance between grips is 75 mm;
- Thickness sample range between 0.1 and 2.5 mm;

- It is possible to perform real time thickness and width variation measurements (thus determining true stress-true strain measurements).

Schematic and real images of the equipment are shown in Figures 1 and 2, respectively.

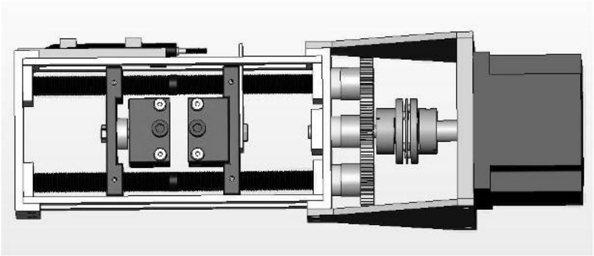

Figure 1 – Micro-tester scheme

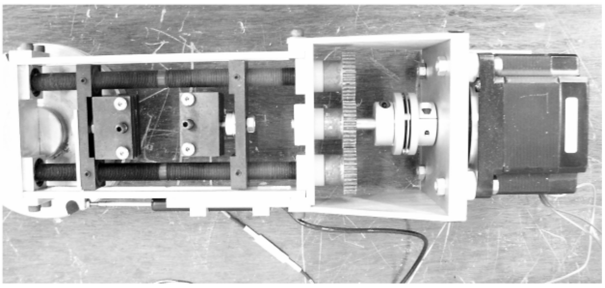

Figure 2 – Micro-tester photograph

All the control of the equipment and data acquisition was developed in LabView. Figure 3 shows the main components of the control and monitoring system (sensors, motors, connectors) and their assembly scheme.

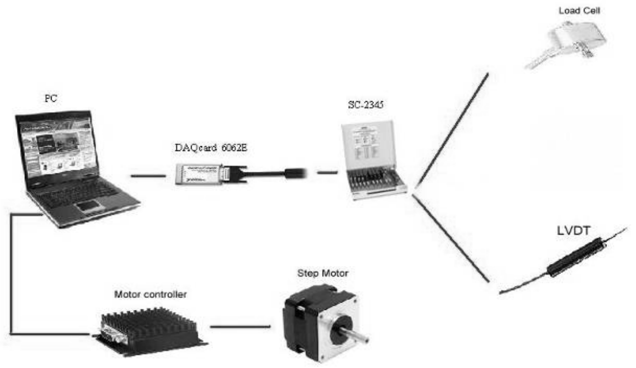

Figure 3 – Main components and schematic connections of the control and monitoring system [6].

In **Figure 3 – Developed software interface** (data input and monitored variables).

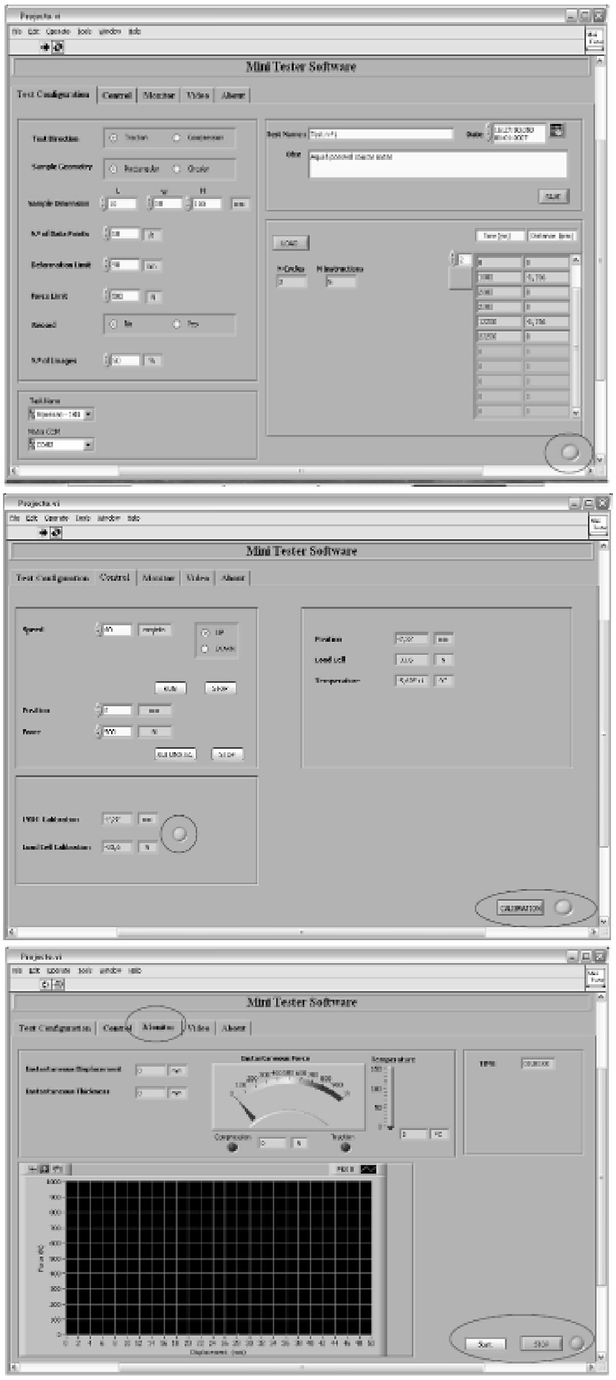

Figure 3 – Developed software interface [6].

The characteristics of this equipment make it very useful to perform the mechanical characterization of micro injected parts.

III EXPERIMENTAL

III.1 MICRO-INJECTION PARTS PROCESSING

Microinjection moulded HPP and MABS parts with a dumbbell shape were produced in a

Battenfeld Microsystem 50 with dimensions and processing conditions shown in Figure 5.

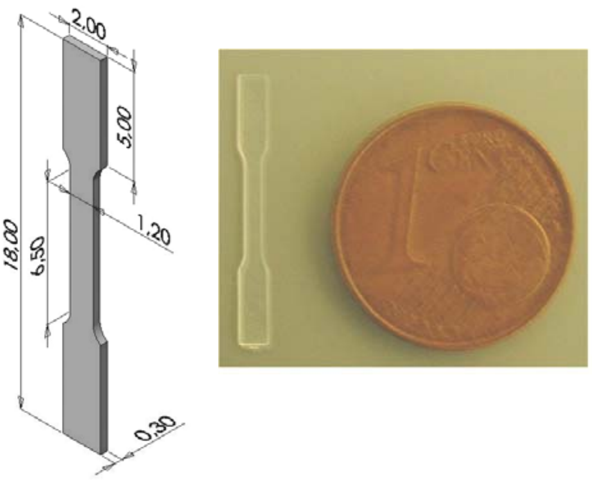

Figure 5 – Dimensions of the microtensile specimens.

In table 1 is shown the adopted moulding programme that considered variations, in two levels, of the mould temperature and injection velocity for both polymers.

Table 1 – Main processing parameters varied.

HPP

Experiment	P. Conditions
1	$T_m = 30$ $V_{inj} = 100$
3	$T_m = 60$ $V_{inj} = 100$
7	$T_m = 30$ $V_{inj} = 300$
9	$T_m = 60$ $V_{inj} = 300$

MABS

Experiment	P. Conditions
1	$T_m = 50$ $V_{inj} = 100$
3	$T_m = 80$ $V_{inj} = 100$
7	$T_m = 50$ $V_{inj} = 300$
9	$T_m = 80$ $V_{inj} = 300$

III.2 TENSILE TEST

The micro-tester was mounted with a 500 N load cell. Tensile tests were performed at a constant velocity of 1 mm/min at room temperature (23 ºC). The tests were repeated for four samples each. The engineering stress-strain curves were obtained.

IV RESULTS

Figure 6 presents the measured tensile stress-strain curves for both polymers that evidence typical evolutions and data values. As expected, HPP shows a lower stress level, but a higher deformation capability when compared with MABS. From these stress-strain curves the yield stress and yield strain was obtained and the data is reported in Table 2 and 3 for HPP and MABS, respectively.

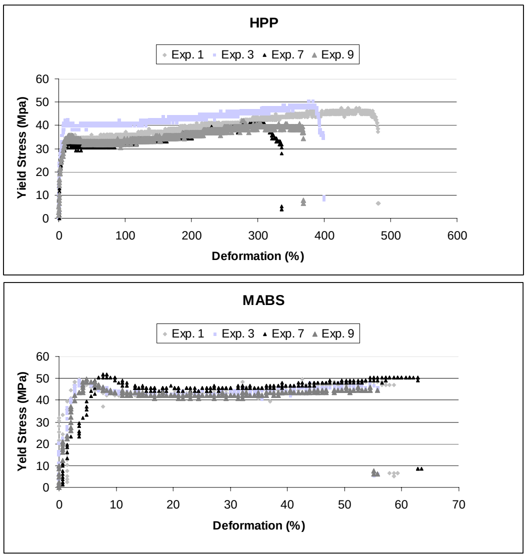

Figure 1 – Stress-Strain curves for HPP and MABS polymers (see table 1 for reference of the experiments).

Table 2 – Yield point data for HPP.

Experiment	σ_y avr. (MPa)	Standard Deviation	ε_y avr. (%)	Standard Deviation
1	34,809	0,376	7,905	1,244
3	41,647	0,903	8,371	0,467
7	33,512	1,618	9,3	0,772
9	33,547	0,344	7,438	1,256

Table 3 - Yield point data for MABS.

Experiment	$\sigma_{y\ avr.}$ (MPa)	Standard Deviation	$\varepsilon_{y\ avr.}$ (%)	Standard Deviation
1	47,091	1,043	4,182	1,396
3	50,859	1,956	4,711	0,875
7	49,931	1,367	5,754	1,218
9	48,468	0,941	4,882	1,046

The stress-strain behaviour allowed the evaluation of the mechanical performance of the injection moulded PP and MABS dumbbell like micro-specimens. For both polymers, the yield stresses are relatively higher than conventional moulded standard (macroscopic) specimens. This should be the result of the expectant high level of molecular orientation induced in microinjected mouldings. As also can be seen in tables 2 and 3 the obtained standard deviations are acceptable and in the range found in standard (macroscopic) tests.

Figure 7 shows the variations of the yield stress with the processing variables. For HPP and at low injection velocity, the yield stress increases with the mould temperature; at high injection velocity there is no influence of the mould temperature. This reveals some degree of interaction between both processing variables. Compared to HPP, MABS specimens show higher Young modulus and stress levels, as already abovementioned. The effect of the processing parameters on the yield stress of MABS specimens is similar to that of HPP. But now, the variations induced by changes of the processing parameters are smaller due to the amorphous nature of MABS (compared with the semicrystalline nature of HPP).

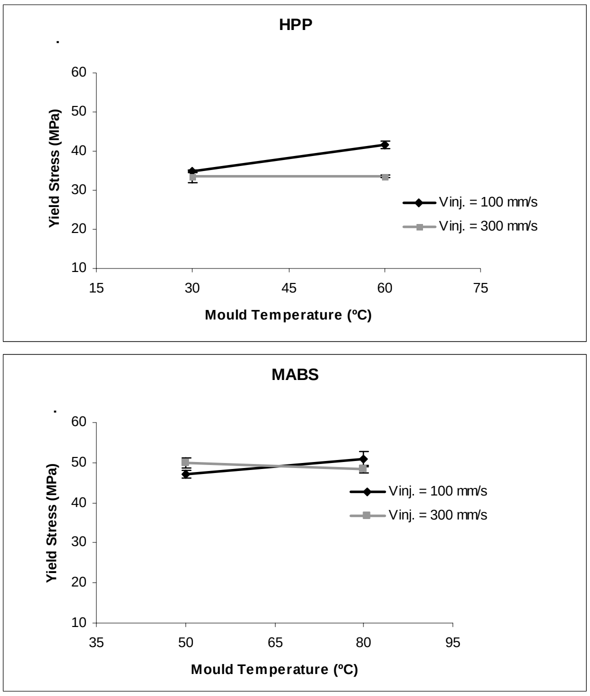

Figure 2 – Influence of processing condition on the yield stress for both HPP and MABS specimens.

Concluding, higher yield stresses were observed on samples obtained with low injection velocity and high mould temperature. This behaviour was similar for both materials. Variation of the selected processing variables was able to induce changes on the yield stress of 24 and 8%, for HPP and MABS, respectively.

In future work will be established the relationships between the processing variables, the developed morphology and the mechanical behaviour of microinjected mouldings.

V FUTHER APPLICATIONS OF MICROTESTER

Further uses of the mechanical micro-tester will consider performing deformation studies in-situ and concomitantly with structural characterization techniques and with measurements of other physical variables (e.g., electric resistivity), especially in mechanically active polymer systems.

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