MECHANICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE COMPOUND FOR PIPES EXTRUDED UNDER THE INFLUENCE OF ULTRASOUND

Robert Withnall, **Ali Ahmadnia, Amir Khamsehnezhad, Jack Silver, Peter Allan and Karnik Tarverdi**
Wolfson Centre for Materials Processing, Brunel University, Kingston Lane, Uxbridge UB8 3PH, Middlesex, UK

Introduction

The application of ultrasound during the extrusion of polymers has the potential to improve melt flow properties as well as the quality of the extrudates; in addition, it may enable some polymer blends to be processed which are otherwise difficult to process by conventional methods. For example, when polystyrene was extruded through a slit die it was reported to show a decrease in viscosity, along with a decrease in die pressure, as ultrasound intensity was increased [1]. Similar effects were found for the extrusion of linear low density polyethylene (LLDPE) under the influence of ultrasound, and the productivity of LLDPE was reported to increase as the ultrasound intensity was increased [2]. In another study, polypropylene was extruded whilst applying ultrasound and again a decrease in viscosity and die pressure was reported and the die temperature increased as the ultrasound intensity increased, resulting in an enhanced throughput of the extrudate [3]. In addition, the mechanical properties of blends of polypropylene and natural rubber have been reported to be significantly better when they have been extruded whilst applying ultrasound [4]. The aim of the present study is to determine the effects of applying ultrasound when extruding a polyethylene pipe blend through a strip die using a 25 mm single screw extruder.

Experimental

Materials
A polyethylene compound containing carbon black that is used for pressure piping (Borstar HE3470-LS (PE80) supplied by Borealis A/S, Denmark) was obtained in pellet form from Polypipe Terrain, UK, and used without further purification.

Polymer Processing
The polyethylene compounds were extruded through a cross-head slit die using a single screw Betol extruder having a screw diameter of 25 mm. The screw speed ranged from 10 to 50 rpm.

The set-up was configured so that the polymer melt flowed around an aluminum sonic horn that was housed in an ultrasonic treatment mould, which interfaced between the extruder barrel and the strip die (see Figure 1).

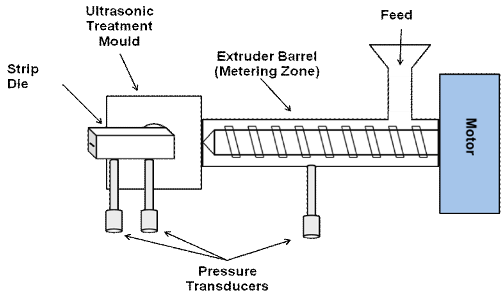

Fig. 1 Schematic of the in-line ultrasonic extrusion set-up.

A 250 W ultrasonic power supply (UM250 ultrasonic generator from Solbraze Ltd., UK) was used to apply ultrasound at a frequency of 20 kHz. The piezoelectric crystal was air-cooled.
Pressure transducers (Dynisco DYN-X-10M-6) were fitted onto the extruder barrel and the strip die so that the pressure drop between the extruder barrel and the die could be measured (see Figure 1).
The temperatures in the extruder barrel section were set at 160, 180 and 195°C from the feed zone to the die zone. Heating elements were also fitted to the ultrasonic treatment mould.

Measurements
The melt flow index of the PE80 compound was measured to be 0.10 g/10 min at a temperature of 190°C, conforming to ASTM 1238, using a Haake MeltFlow ST and applied loads of 5 kg.
The tensile properties were measured at room temperature with an Instron tensile testing machine on specimens cut from strips from the die. The tests were carried out at a crosshead speed of 1 mm/min and an initial gauge length of 25 mm for the modulus measurements, and at 5 mm/min and an initial gauge length of 50 mm for the other tensile measurements.

Results and Discussion

Figure 1 shows a comparison of the stress-strain (s-s) curves on the specimens of the PE80 blend which had been cut from strips that had been produced by extrusion in the presence and absence of ultrasound. The specimens that had been extruded under the influence of ultrasound underwent strain hardening at strains beyond the yield point, as can be seen from Figure 2.

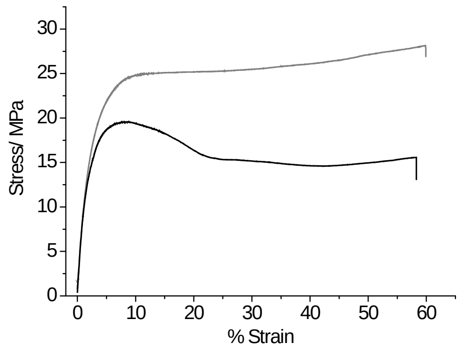

Fig. 2 Stress-strain curves for specimens of the PE80 blend that have been extruded in the presence (gray line) and absence (black line) of ultrasound.

The percentage increase in the tensile strength is greater at lower screw speeds, as can be seen from Figure 3. This is because the residence time in the ultrasonic chamber is longer at lower screw speeds, resulting in a longer exposure of the polymer melt to ultrasonic irradiation.

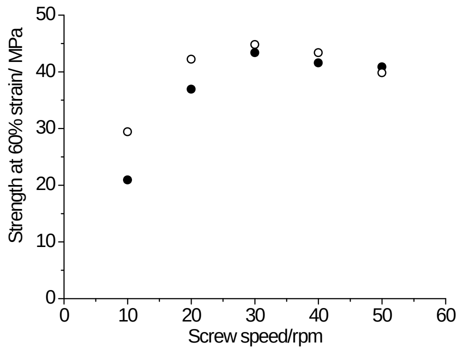

Fig. 3 A plot of tensile strength versus extruder screw speed for polyethylene specimens that have been extruded in the presence (open circles) and absence (solid circles) of ultrasound.

It was also apparent from DMA tests of the PE80 blend that ultrasound enhanced the storage modulus in the -150 to 60°C temperature range (see Figure 4), most likely due the effect of the ultrasound on the thermal motion of the polyethylene chains.

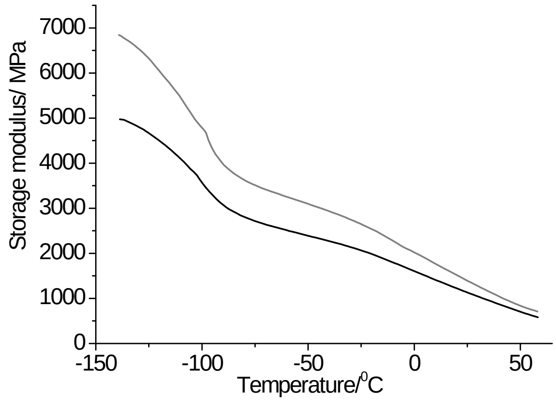

Fig. 4 DMA results for specimens of the PE80 blend that have been extruded in the presence (gray line) and absence (black line) of ultrasound.

Conclusion

The mechanical properties of samples of the PE80 pipe blend that had been extruded in the presence and absence of ultrasound were compared. By applying ultrasound at the interface of the extruder barrel and die, strain hardening of the PE80 extrudate was observed and the tensile strength was increased. The percentage increase in tensile strength was greater for slower screw speeds, when the exposure time to ultrasound irradiation was longer. In addition the DMA results showed an increase in storage modulus. It is apparent that the application of ultrasound during the extrusion of PE80 pipe blends can affect the mechanical properties of the extrudates.

References

1. Yingzi Chen, Huilin Li, Effect of Ultrasound on the Viscoelasticity and Rheology of Polystyrene Extruded Through a Slit Die, *Journal of Applied Polymer Science*, **100** (2006) 2907–2911.
2. Shaoyun Guo, Yuntao Li, Guangshun Chen and Huilin Li, Ultrasonic improvement of rheological and processing behaviour of LLDPE during extrusion, *Polym Int*, 52 (2003) 68–73.
3. Yurong Cao and Huilin Li, Influence of Ultrasound on the Processing and Structure of Polypropylene During Extrusion, *Polymer Engineering and Science*, **42** (2002) 1534-1540.
4. Jeong Seok Oh, A. I. Isayev, and M. A. Rogunova, Continuous ultrasonic process for in situ compatibilization of poly-propylene/natural rubber blends, *Polymer*, **44** (2003) 2337-234.