Breakthrough in studying POLYMER FLOW IN TWIN SCREW EXTRUSION

Introduction

The PEPTFlow project can announce that it has successfully tracked the flow of polymer through a Leistritz Micro 27 co-rotating twin screw extruder. This is the first time that the flow can be tracked in real time and under realistic processing conditions. These groundbreaking results are being used to improve the general understanding of twin-screw extrusion and screw design, and the modelling of flow and mixing in simulation and optimisation software. The results are currently being interpreted in a number of ways and a 3D visualisation of the early results can be seen at the project website, www.peptflow.com , or on Youtube. The video shows the paths of real particles moving through a twin-screw extruder. This is a large step forward from Perspex barrels, small windows and stop start techniques by allowing quantitative analysis as well as qualitative.

The Project

The project is funded under the European 6th Framework programme. There are 20 partners in the project including 4 research partners, 5 industrial associations and 11 SME's. The project started in September 2006, has a total funding of €3.35 m and will run until December 2009. Many technical challenges have been successfully overcome to obtain results from this project. The PEPT technique, originated at Birmingham University, has been further developed from the study of thin walled batch processes to the study of a continuous process in a predominantly steel extruder.

PEPT Technique

PEPT or positron emission particle tracking is a variant of the medical technique positron emission tomography (PET) and uses modified detector equipment from hospital scanners. The tracer particle starts life in a cyclotron. Oxygen atoms are bombarded with alpha particles and a small proportion are converted to Fluorine 18. In this project the oxygen is water and the active water is concentrated and absorbed onto a carrier such as an Alumina. The Alumina particles are about 100 microns in diamenter. The Fluorine 18 has a half-life of 109 minutes and decays back to Oxygen 16 by emitting a positron and a neutrino. The positron collides with an electron in the near locality and is annihilated producing a pair of back-to-back gamma photons. These photons are detected by the camera device. The camera is constructed from components from obsolete PET scanners used in hospitals. The camera has been constructed in a ring arrangement to give a 360o field of view. The camera detects thousands of readings every second and by pairing results can locate the particle to a few hundred microns.

Extruder

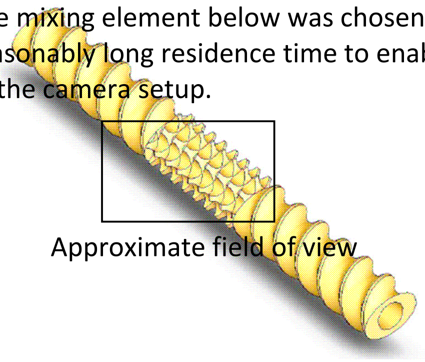
It was known that PEPT could monitor flow in fluids but the difficulty was to overcome all the absorbing power of metal that makes up a twin-screw extruder. For the experiments it was decided to use a Leistritz Micro 27 extruder fitted with Brabender feeders. Early tests showed there was still too much metal in the machine to give accurate results, so a special section was designed and built that would be more transparent to the gamma photons. The "PEPT window" is an Aluminium barrel section and gives about 100mm or 3D of screw to study. A particle separation device installed after the pelletiser was designed and built by ICT Fraunhofer. A Geiger counter detects the particle in the strand as it enters the pelletiser and, after a suitable delay, activates the separation flap to divert the stream of pellets to a collection box from which the active pellet can be straightforwardly recovered using the Geiger counter.

Results

The first PEPT studies of polymer melt flow in a twin screw extruder have been carried out and work continues to optimise and evaluate the data output from the camera. In the meantime, the figures below give an indication of the quality and type of data that has been generated from one of the runs.

Screw Configuration

The mixing element below was chosen to give a reasonably long residence time to enable optimisation of the camera setup.



Operation

Polymer: DOW C711-RNA
Polypropylene Resin

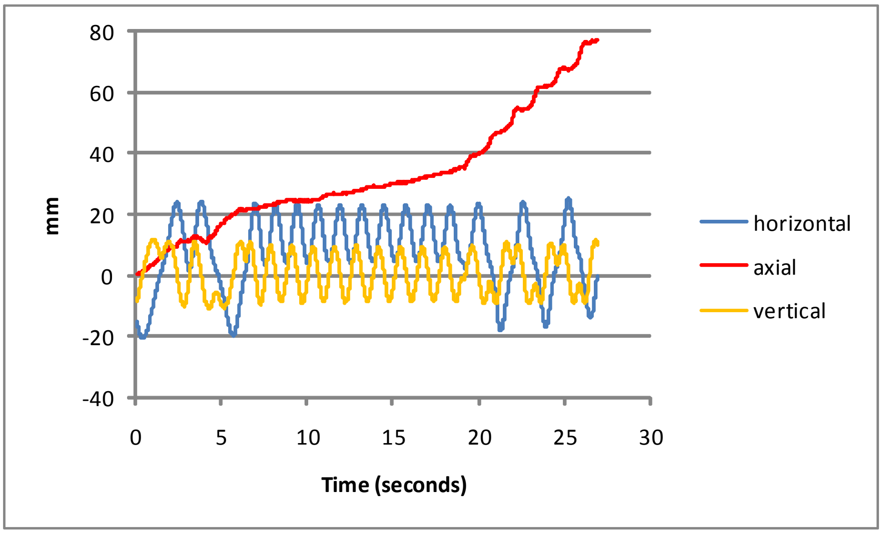
Shaft Speed: 60 rpm

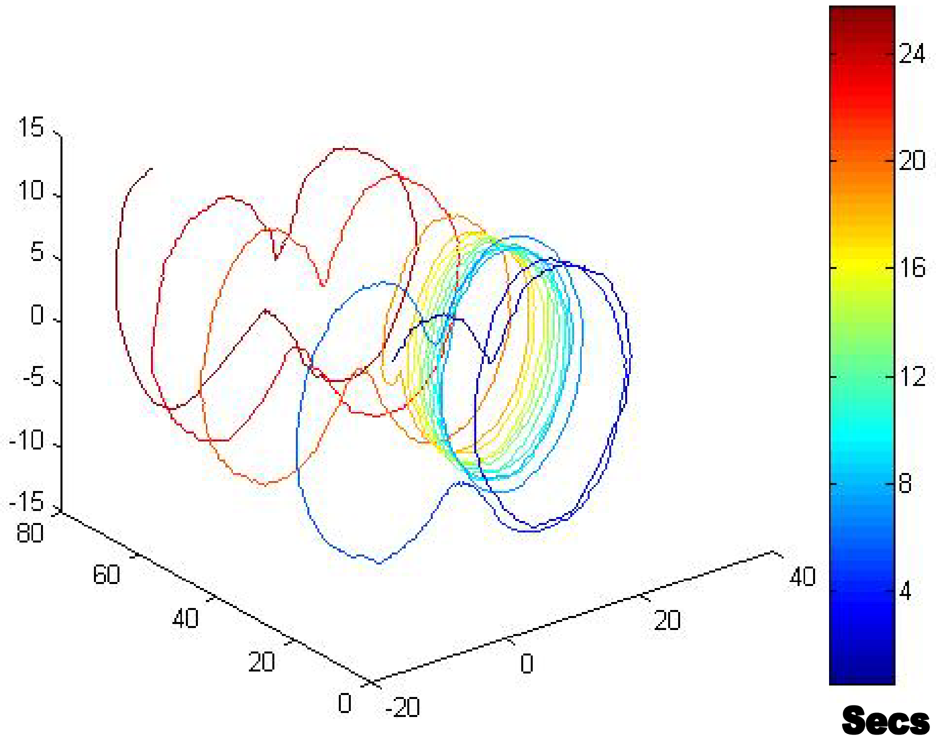
Polymer Feed Rate: 4.5 kg/hr

Temperature: 220°C

Example Trajectory

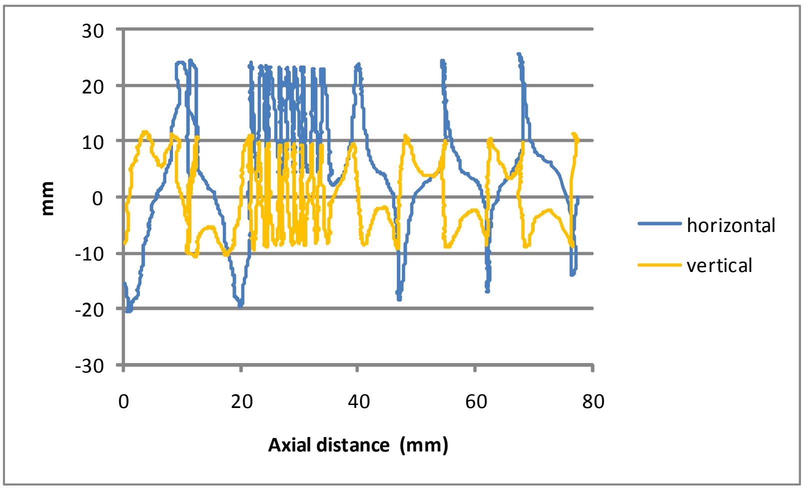
This figure shows the horizontal, axial and vertical position of the particle as it moves through the extruder window. In this trajectory example, the particle spends a considerable period on one side of the barrel and the axial velocity, while steady, is much slower during this period.



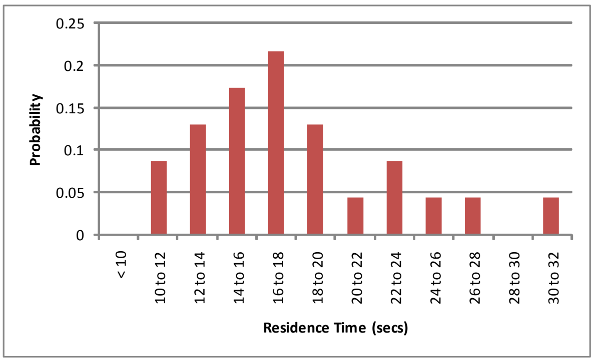


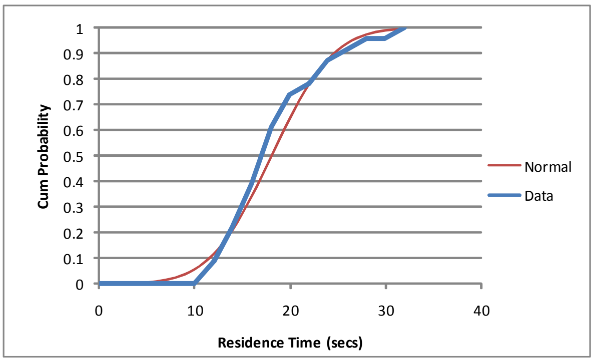
3D plot of the particle moving through the extruder. The trajectory is colour coded according to the time spent in the field of view.

This shows the horizontal and vertical movement of the tracer as it moves axially through the extruder. The axial movement increases significantly as the particle crosses from one side to the other through the meshing region where the polymer is squeezed predominantly forwards.



Average residence time and residence time distribution through a section of screw can be obtained, as shown below:





Residence time distribution for multiple passes through the field of view. Residence time measured between 10mm and 80mm.

Work is also progressing to calculate other data such as particle velocity, acceleration, occupancy in specific areas and passes through high shear regions such as nips and tips.

Software and case studies

Some of the results from the PEPT studies will be used to validate new mixing software that is being produced by the Technical University of Eindhoven. This software is designed to be run quickly on a PC and uses a development of the mapping method developed there. This will also be integrated in to the commercial Ludovic software developed by SCC.

The project will also undertake a number of case studies to demonstrate the value of the new software and the PEPT technique. These case studies will also be part of the dissemination exercise.

Dissemination

A number of training events will be organised by the Industrial Association partners to disseminate the major findings of the project. These will be held at during the second half of 2009 and details will be available on the project website.

Project Consortium

SMEs

CESAP

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