Project no. 505204-1

APT_PACK

Advanced knowledge of Polymer deformation for Tomorrow's PACKaging

Instrument: STREP

Thematic Priority: NMP – PRIORITY 3

Publishable Final Activity Report

Period covered: from 01/10/06 to 31/03/08 Date of preparation: 08/09/08

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The long-term objective of the project is the definition of a global strategy for optimising stretched plastic packaging (thermoforming, stretch blow moulding). To compensate for the lack of basic understanding that strongly inhibits durable improvements, scientific objective is promoting attainments and applications of fundamental knowledge. The strategy is to propose tools that are necessary for building straightforward correlation between the structure of polymers, its relevance to packaging and the end-use properties of products. This is achieved thank to fundamental studies of the material and of the role of its microstructure. Two of them aim at developing correlation between microstructure and final properties and on the evolution of microstructure during processing, respectively. Processing is known to enhance coupling between the processing and the microstructure, while boundary conditions are not totally controlled. Consequently, specific researches are devoted to the understanding of the processing. Finally, as the rheology of polymer is a key issue, an important work is devoted to the proposal of constitutive models relevant for thermoforming and/ or stretch blow moulding. The project focuses on the three types of polymers used in this area: amorphous, semi-crystalline and initially amorphous that crystallise during forming. To allow long-term improvement, significant efforts are devoted to physically based approaches.

Main project direct outputs are:

- Advanced knowledge in the field of polymers stretching.
- Proposal of relevant physically based constitutive models
- Development of high velocity multi-axial loading tests in the range of thermoforming and blowing.
- Advanced knowledge in the field of microstructure development
- Proposal of physically based constitutive models for end-use properties.
- Advanced knowledge in the field of processing, including heating, stretching and cooling.
- Proposal for next generation numerical codes for design.

The partnership regroups 16 highly complementary partners of 9 nationalities including 2 candidates (Portugal, Germany, United Kingdom, Ireland, Spain, Turkey, Hungary, Switzerland and France).

The 8 industrial partners allow covering the entire supply chain- from the supplier to the end-user-, which is a crucial issue for dissemination. The 2 resin suppliers allow studying most of the polymers generally used in such applications. Consortium involves SMEs either directly, or indirectly through the involvement of a non-profit organisation that represents 800 companies among which lot of SMEs.

Main activity of two end-users is related to food delivery and medical applications that are domains where reliability and control are of prime importance. The main activity of one partner is refrigerator inner liner thermoforming. With respect to quality demands, this domain is not a totally disconnected area, but nevertheless represents an opportunity of promoting dissemination towards other domains of plastics industry.

The 8 R&D performers are skilled in their domains and their main competence is significantly different but highly interconnected. This allows covering all levels to be considered: polymer stretching, microstructure development, processing and end-use properties including packaging vs. food interactions and legal aspects. Some R&D and industrial partners are used to develop co-operation on equivalent domains at a national level. This project will be an opportunity to promote co-operations at a European level. R&D performers are, for their parts, already involved in common international project. This project will be an opportunity to enlarge and reinforce existing academic co-operations.

Each partner will contribute with its expertise and resources to several working tasks. They however will be charge of specific tasks that are emphasised.

Today consortium agreed on defining main materials to be studied and supplies them for all the project duration. These materials are industrial grades especially designed either for stretch blow moulding or for thermoforming.

Representative industrial parts, specific moulds (one for PET, one for PP), associated preforms and systems for data acquisition during processing are available. A significant data base now exists on actual heating, thermal contact, loading histories and friction in processing, which will improve fundamental knowledge in processing and validations of numerical simulations.

Bi axial and planar test are available over the entire range of strain rate and temperatures. Large amounts of experimental data have been gathered in uni axial, planar and bi axial conditions for all types of materials: amorphous, semi-crystalline and exhibiting strain-induced crystallisation.

Three physically based constitutive models were developed and validated that can be implemented in commercial software.

Microstructure development is studied combining.

- ✓ Optical microscopy or small angle light scattering that gives access to spherulite sizes;
- ✓ Global birefringence that characterizes the overall orientation of the materials;
- ✓ DSC that allows to estimating crystallinity ratio melting and crystallization temperature;
- ✓ Wide X ray scattering (WAXS) that gives access to the identification of the crystalline system and to crystalline orientation;
- ✓ Small angle X ray scattering (SAXS) that leads to information concerning the orientation and the lamellar arrangement;
- ✓ TEM observation that allows observation of lamellar structure;
- ✓ As far as PET is concerned, IR spectroscopy that gives access to molecular orientation;
- ✓ DMA spectrometry that gives information on amorphous phase through its relaxations.

Specific protocols allow analysing crystalline evolution kinetics as a function of loading conditions. Development of specific bi-axial micro machine for X-ray in situ measurements is almost achieved. Access to synchrotron facilities is planned for specific microstructure analysis.

End-use properties (mechanical, optical and barrier properties) are studied as a function of structure development and processing. Consequently, all experimental work carried on concerning end use properties is connected to a “sister task” for microstructure characterisation. Work is in progress but some data were already gathered.

All together, data bases are of unusual richness. They concern the same materials, processed in the same manners from the very simple (compression) to the most complex (stretch blowing) using unique sets of performs and mould.

Measurements were performed according to same protocol. Direct relationships between processing / loading, microstructure and end use properties can than, be searched for without any ambiguity, except scientific ones.

One portable equipment dedicated to data acquisition on industrial stretch blow moulding machine ands instrumented mould had been developed and are now available.

Concerning dissemination two seminars were held to diffuse the project results achieved:

- ✓ On April 06 in conjunction with the PPRC 10th Anniversary Conference (Belfast, United Kingdom) Website is available.
- ✓ On October 2nd 2006 in Caiscas.

A specific final workshop was held in Paris on Marh 10th 2008.

Two PhD will be defended in 2008 by ARMINES one in CRoMep (M. Bordival) and one in CEMEF (M. Picard). Manuscrpts will be public and available in PASTEL website.

During project 28 publications have been done by partners in the areas of the project.