ChE laboratory

POLYMER PROCESSING AT BROOKLYN POLY

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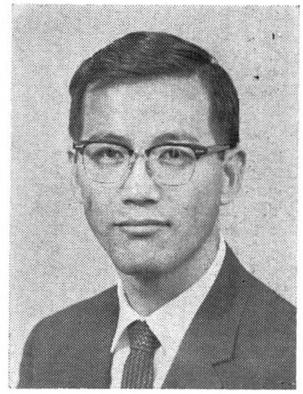
POLYTECHNIC INSTITUTE OF BROOKLYN (PIB) has long been recognized as a stronghold for education and research in polymer science and engineering. More than thirty years ago, a world-renowned polymer chemist, Dr. Herman Mark, started the polymer science program and established the Polymer Research Institute in the Chemistry Department.

In the Department of Chemical Engineering, Professor Paul F. Bruins has devoted his entire professional career during the past 35 years to education and research in Polymer Engineering Technology. The first graduate course in Plastics Technology was organized in 1939 with the encouragement and assistance of Mr. Charles Breskin, publisher and editor of the Modern Plastics Magazine. After World War II, an optional program of four courses in Polymer Chemistry and Engineering was offered as part of the undergraduate program in Chemical Engineering. These include Polymer Chemistry Plastics Technology and Plastics Design. This option was very popular and was continued until 1964, when the program was expanded and organized into a graduate curriculum. In 1964, Professor Bruins was fortunate to have obtained a donation from one of his former students, Mr. Jerry M. Sudarsky, then General Manager of International Minerals and Chemicals Corporation. The donation was made to help Professor Bruins set up a Polymer Processing Laboratory in the Department of Chemical Engineering. The Laboratory was initially equipped with some basic processing equipment, such as an extruder with rod, tub and film forming dies, injection molding machine, blow molding machine, rubber roll mill, thermoformer, compression molding press, as well as a variety of test equipment.

POLYMERIC MATERIALS PROGRAM AT PIB

With the newly equipped laboratory facilities the Department of Chemical Engineering has introduced a new graduate degree program called



Chang Dae Han has a BS from Seoul National University; and MS and ScD ('64) from MIT all in chemical engineering. In addition, he earned an MS in electrical engineering from Newark College and an MS ('70) in mathematics from the Courant Institute at NYU. He has industrial experience with American Cyanamid and Esso Research and Engineering. His research interests are in applications of functional analysis to ChE systems, polymer rehology as applied to polymer processing, and biorheology as related to clinical applications.

the Polymeric Materials Program. This program is aimed at meeting the interests of graduate students, as well as industrial scientists and engineers, who wish to keep up with the rapidly growing field of polymer engineering technology. Since the program stresses the engineering aspect of polymer science, it has offered during the past several years such subjects as: Introduction to Polymeric Materials, Polymer Processing, Engineering Properties of Polymer, Polymer Manufacture, Polymer Engineering Laboratory. Organic Coatings Technology, Selected Topics in Polymeric Materials.

Students in the Polymeric Materials Program are also required to take some basic courses in polymer chemistry in the Chemistry Department, such as: Introduction to Polymer Chemistry, and Polymer Chemistry Laboratory. Other advanced topics in polymer chemistry are left as options to those who wish to take them.

Since 1967, a new course, Rheology of Non-Newtonian Fluids, has been added to the Program. This course, which is taught by the writer, has been offered to students in the regular Chemical Engineering Program and also in the Polymeric Materials Program. Its emphasis has been to teach the modern concept of polymer rheology from both the continuum and molecular points of view, to help students analyze data obtained by various experimental techniques and to illustrate how to rigorously treat some of the really complicated problems encountered in industrial polymer processing (e.g. fiber extrusion, blow molding, and extrusion in various die geometries).

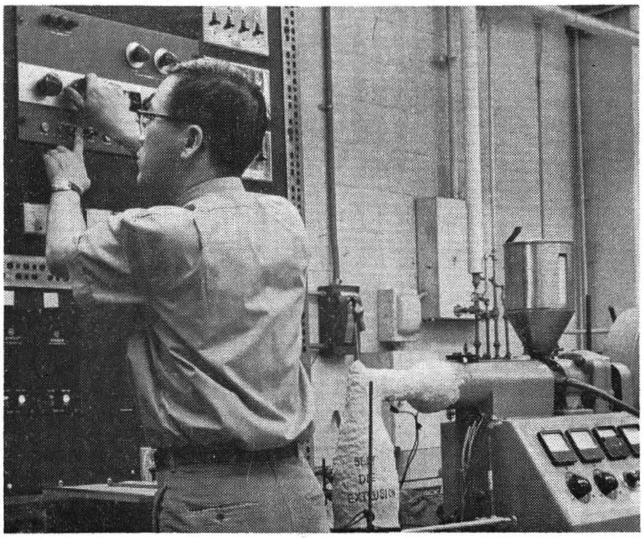


Figure 1.—The writer was taking normal stress measurements with a slit die.

POLYMER PROCESSING IS A COMPLEX SUBJECT

Because of the invention of new processes and improvements in existing ones, the processing technology of polymer materials has undergone a considerable evolution during the past decade. A good understanding of any industrial process requires knowledge in many branches of science and engineering, such as polymer chemistry, mechanics of non-Newtonian viscoelastic fluids, mass and energy transport. For instance, many beautiful theories developed in the area of continuum mechanics alone are not much help in explaining such a simple experimental fact as "A polymer having much long-chain branching is less viscous, and yet more elastic, than one having little or no long-chain branching." This simply illustrates the fact that, in order to understand many as yet unanswered questions, knowledge of both the molecular aspect of macromolecular structures under deformation and the phenomenological aspect of viscoelasticity theories will be required.

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To illustrate the point, let us consider perhaps one of the most well-known polymer operations, fiber spinning. Regardless of any specific fiber spinning techniques (wet-, dry-, or melt-spinning), an understanding of fiber spinning requires a knowledge of momentum, energy and/or mass transport. In addition, knowledge of macromolecular behavior under deformation is also necessary fgor understanding such complicated problems as molecular orientation under stretching, crystallinity under cooling, surface characteristics of the threadline being stretched and cooied, so-called surface morphology, etc.

There are many other polymer processing techniques, which need to be better understood at the fundamental level. To name some typical industrially important processes: extrusion (single and multiple screw), fiber spinning, film extrusion, cold drawing, blow molding, thermoforming, injection molding, extrusion through noncircular dies, etc.

POLYMER PROCESSING RESEARCH IMPROVES LAB TEACHING

It is not common to find a Graduate Chemical Engineering curriculum which includes a laboratory course. In this sense, the Polymeric Materials Program is unique in that it includes the Polymer Engineering Laboratory course. This course is intended to teach several different types of experimental techniques and to apply the knowledge learned in the classroom to actual processing.

It is to be noted that a majority of industrial polymer operations deal with bulk polymers, which necessitates understanding the rheological behavior of polymer melts. An obvious reason for the use of melts, instead of polymer solutions, is the economics involved. The use of bulk polymers avoid the frequently difficult and costly operation of solvent recovery at the end of the processing line. On the other hand the handling of polymer melts is more difficult than that of polymer solutions. In particular, handling polymer melts requires some extra precautions. For example, a failure of the temperature control system may give rise to degradation of polymers in the equipment, and could even cause an explosion.

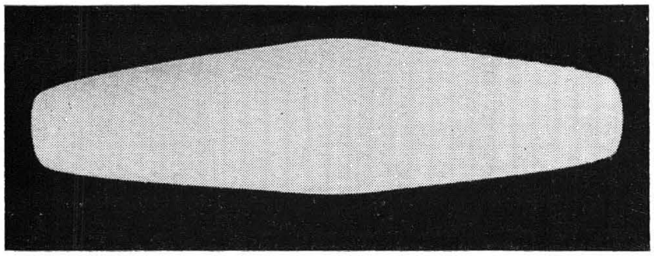

Figure 2.—Extrudate swell behavior of high density polyethylene from a rectangular duct at 200°C.

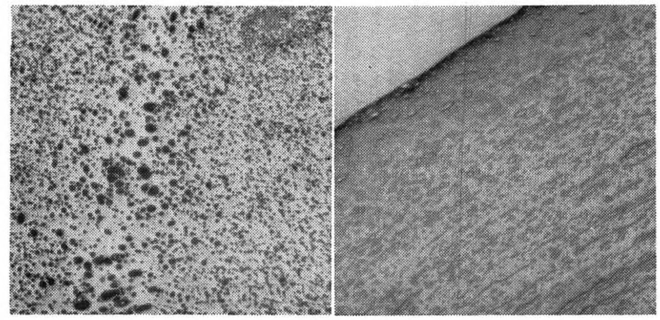

Figure 3.—Micrographs of an extrudate of 20wt% polystyrene-80wt% polypropylene at 200°C; (a) at center portion of the cross-section; (b) in the longitudinal direction.

During the past four years, the writer's research activities have added some new laboratory facilities to those already existing. They include capillary and slit extrusion dies (essentially melt rheometers—see Figure 1), melt-spinning equipment and wet-spinning equipment. Some of these have already been used for the Polymer Engineering Laboratory course. In the very near future, a new annular die for blow film extrusion will be added. A small semi-automatic blow molding unit has been used in the laboratory course to show students how to make hollow objects like bottles. However, an analysis of polymer melt flow through complicated flow paths (i.e., other than circular and slit geometry) is very difficult, and awaits future research. Therefore, the addition of the annular die should be instructive, because the analysis of polymer melt flow through such geometry is rather straightforward.

Recently, we have been involved with a variety of research projects in polymer melt rheology and polymer processing. Some of the experimental observations made in our laboratory have been discussed in our classroom and laboratory courses. Two of the recent observations made seem to be of some general interest to our readers. These are shown in Figures 2 and 3. Figure 2 shows a cross-section of an extrudate of high density polyethylene, extruded through a rectangular duct of an aspect ratio of 6. Here the aspect ratio is defined as the ratio of the long side to the short side of rectangle. It is interesting to observe from Figure 2 that swelling at the center of the long side is much more pronounced than at the center of the short side. An analysis of this experimental observation has been given in a recent paper by the writer.[1] Figure 3 shows microstructures of an extrudate of 20wt% polystyrene-80wt% polypropylene mixture extruded through a circular die of an L/D ratio of 20, at 200°C. The dark areas in the pictures represent polystyrene, which is disparsed in the contінous phase, polyprópylene, shown white. It is interesting to note from Figure 3 that mixtures of polystyrene and polypropylene form a two-phase system in the molten state. The observation has led us to involve ourselves deeply in an extensive research program of studies of two-flow of viscoelastic fluids. Some of the earlier studies have already been reported in the literature.[2] It seems worth pointing out that there are a number of industrially important polymeric materials, which form two phases in the molten state. High impact polystyrene and acrylonitrile-butadiene-polystyrene (ABS) resins are typical examples.

In recent years, Professor Bruins has been interested in thermoforming process, and has developed an experimental technique, which employes measurements of uniaxial tensile creep to predict thermoforming behavior. This technique is believed to be very useful for predicting optimum temperatures for thermoforming and for comparing the thermoformability of various thermoplastic sheets.

We have tried, and will continue, to maintain a close contact between our polymer processing research and laboratory teaching in the of polymer rheology and polymer processing. We believe that our students can directly benefit from ourresearch projects. We further hope that our continuing interest in this field will continuously improve the experimental program in the Polymer Engineering Laboratory course. □

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