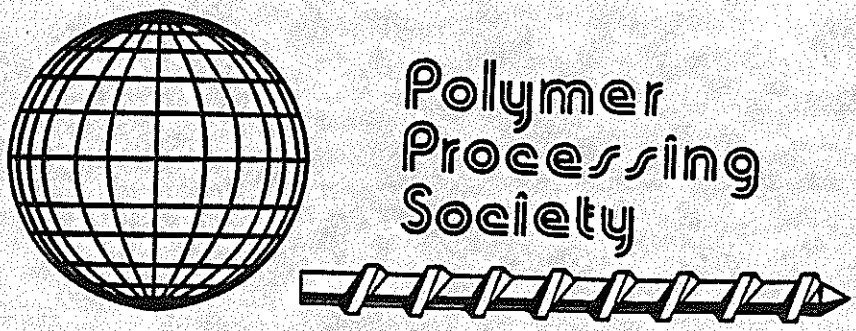
FOUNDING MEETING
OF
THE POLYMER PROCESSING SOCIETY

MARCH 28-29, 1985

AUBURN SCIENCE CENTER
SCHRANK HALL
THE UNIVERSITY OF AKRON



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ABSTRACTS

for

1ST ANNUAL

POLYMER PROCESSING SOCIETY MEETING

MARCH 28 - 29, 1985

UNIVERSITY OF AKRON
AKRON, OHIO 44325

THURSDAY, MARCH 28

SHS - Petrie Auditorium, 8:40 a.m.

Plenary Lecture

CAD AND CAE IN PLASTICS PROCESSING

G. Menges
Institut fur Kunststoffverarbeitung
RWTH Aachen
Pontstrasse 49 - D-5100
Aachen, West Germany

Abstract

The lecture gives a review of the state in the use of computers in planning in plastics manufacturing plants. It will be shown which are the final goals and what software is available today. There are existing different needs in molding design, mold design, extrusion, and machinery producers. This will be discussed. Finally the costs and the assumed return of investment are presented.

Session I, ASC Room 120, 10:00 a.m.

CALCULATION AND OPTIMIZATION OF MELT EXTRUDERS

H. Kuhnle
Institut fur Kunststofftechnologie
Boblinger Strasse 70
D-7000 Stuttgart 1, West Germany

Abstract

A three-dimensional finite difference method for computing the flow of polymer melts in screw channels is presented. Using a cylindrical coordinate system, the influences of channel curvature and melt sticking at the screw flight are fully considered. Furthermore, the pseudoplastic behavior of the melt as well as the development of velocity and temperature distributions in corss-sections perpendicular to the screw axis are included. Performance characteristics are given as dimensionless mastercurves in order to provide a universal designing aid for melt extruders and metering zones of plasticating screws.

Extensive measurements have been done confirming the agreement between experience and theory.

As a special application, the otpimal geometery (channel depth and pitch) of a melt chilling exturder for a particular material were determined. In this example, the objectives of optimization were the power absorption, the outlet temperature, and the thermal homogeneity, resp.

Ref: H. Kuhnle, "The Flow of Polymer Melts in Screw Channels", German Plastics 73 (1983).

THURSDAY, MARCH 28

Session I, ASC Room 120, 10:45 a.m.

DYNAMIC MODELLING AND ON-LINE PROCESS CONTROL OF SINGLE SCREW PLASTICATING EXTRUSION

L. James Lee
The Ohio State University
Department of Chemical Engineering
121 Koffolt Labs
140 West 19th Avenue
Columbus, OH 43210

Abstract

Dynamic responses of a single screw plasticating extruder were studied in open-loop tests. Laplace transfer functions and a kinetic-elastic model were developed to simulate the short term and long term responses of pressures, temperatures and extrudate thickness. Results from the dynamic modelling were applied to the closed-loop computer control of extrudate dimension. Four control methods: a conventional PE feedback controller, the Smith predictor, a feedforward plus feedback controller, and an adaptive feedforward plus feedback controller were tried for both set point changes (i.e., extrudate thickness change) and load changes (i.e., screw speed change). It is found that the feedforward type of controllers worked much better than the feedback type of controllers for short term disturbances if the flow model used in the feedforward controller is accurate.

Session I, ASC Room 120, 11:15 a.m.

TWIN SCREW EXTRUSION - STATE OF THE ART

Kurt Eise
Director of Technology
Werner Pfleiderer Corporation
663 E. Crescent Ave.
Ramsey, NJ 07446

Abstract

This paper will discuss theory of twin screw machanism and wide application in compounding and mixing of plastics and rubber products. Laboratory results as well as commercial operating systems data will be discussed for:

* Modifying engineering plastics with fillers and reinforcers

* Compounding and shaping of a specialty sheet product in one heat

* Devolatilization of Plastics

An outlook on future emerging extrusion applications will also be presented.

THE PROCESSING OF THERMOPLASTICS CONTAINING HIGH LOADINGS OF LONG AND CONTINUOUS REINFORCING FIBRES

J.B. Cattanach
G. Cuff
F.N. Cogswell

Imperial Chemical Industries PLC
PO Box No 90
Wilton Middlesborough
Cleveland TS6 8JE England

Abstract

Thermoplastics containing more than 50% by volume of continuous fibre reinforcement have recently been introduced as structural composite materials - "Aromatic Polymer Composites". In a parallel development, a new range - "Verton" - of long fibre injection moulding compounds containing typically 30% by volume of fibres up to 10 mm long is being explored. Both these developments depend on the wetting of the individual fibres by viscous polymer melts which confers on the systems an unprecedented balance of stiffness, touchness and environmental resistance. However, this new balance of properties can only be utilised if these materials can be processed effectively and efficiently into useful end product forms. In this paper we explore the strategies currently being developed to carry out such processing operations and review the critical rheological and morphological properties which permit solutions to such paradoxies as: the production of double curvative mouldings from thermoplastics reinforced with 60% by volume of continuous inextensible fibres; and, the injection of complex form mouldings containing 40% by volume of randomly oriented fibres having an aspect ratio in excess of 100 and a length several times that of the injection port.

THURSDAY, MARCH 28
Session II, ASC Room 122, 10:45 a.m.

NEW TYPE OF SHORT FIBER REINFORCED RUBBER COMPOSITES

Shinji Yamamoto, Kunio Oda, Yukihiko Asano,
Sadao Hoshino, and Kouji Yamaguchi

Chiba Laboratory
Ube Industries, Ltd.
8-1 Goiminamikaigan, Ichihara
Chiba 290 Japan

Abstract

We report on two types of the new rubber composites reinforced by the fibers, having a small diameter and strong adhesive force between fibers and the rubber matrix. UBEPOL-VCR is a polybutadiene rubber in which the fibrils of syndiotactic-1, 2-polybutadiene are uniformly dispersed in the BR matrix. In the black filled compound of VCR/NR, the green stress strain curve rises up more rapidly than in that of BR/NR and the green strength is twice as high as in that of RB/NR. X-ray diffraction diagrams show that the crystallization of the matrix already occurs at 300% elongation of VCR/NR, while it does not do so even at 600% elongation of BR/NR. A similar effect was found in the nylon 6-NR system. The rubber composites which are reinforced by the fine fibers grafter by 10 wt% of NR molecules and having a diameter of 0.2 μm are prepared by the following method. The mixture comprising nylon 6-NR graft copolymer is extruded above T_m of nylon 6 and then the extrudate is drawn below T_m. The fine fibers of nylon 6 are significantly effective in raising the green modulus and strength without increasing Mooney viscosity.

Session II, ASC Room 122, 11:15 a.m.

MELT PROCESSING OF POLYMER LIQUID CRYSTALS

John F. Fellers, David N. Lewis, and Gregory W. Farell

Department of Materials Science and Engineering
The University of Tennessee, Knoxville, TN 37996

Abstract

This paper reports and discusses experiments concerning the level of uniaxial orientation developed in fibers as well as the character and extend of biaxial orientation developed in both tubes and films. In fiber studies, we find that PHB/PET 60/40 (p-Hydroxybenzoate-co Ethylene Terephthalate) does not attain the high Herman Orientation Factor, $F_H > 0.95$, that is routinely obtained for wetspun Kevlar® fibers. To show the effect of an isothermal "gap" on uniaxial orientation, we will discuss the dependence of F_H on both spinline kinematics and temperature when spinning with isothermal and nonisothermal exit regions. Another aspect of our research has been to create a process that can take advantage of the thermotropic liquid crystalline behavior of cellulose ethers to control polymer chain orientation. An annular die consisting of a rotating inner core and a simultaneously counter-rotating outer cylinder was used to obtain various chain orientations. The inner core and outer cylinder rotation speed was used to vary the flow profile. As the ratio of the tangential wall shear rate to the axial wall shear rate (R) was increased, the polymer chain axis moved from the machine to the transverse direction. Nitrogen gas was fed through the inner core to inflate the tubes and produce thin films. Optical birefringence, wide angle x-ray diffraction (WAXS), mechanical properties, and pole figure analysis were used to evaluate the tubes and films produced. Tubes and films with very high levels of biaxial orientation were developed from HPC (Hydroxypropyl Cellulose) and EC (Ethyl Cellulose) using the described process.

Session III, ASC Room 205, 10:00 a.m.

PROFILE DEVELOPMENT IN DRAWN HOLLOW TUBES

B.D. Freeman, M.M. Denn, and R. Keunings

Center for Advanced Materials
Lawrence Berkeley Laboratory
and
Department of Chemical Engineering
University of California
Berkeley, CA 94720

and

G.E. Molau and J. Ramos

Dow Chemical U.S.A.
Walnut Creek, CA 94598

Abstract

Profile development in isothermal drawing of hollow tubes is studied using finite-element and asymptotic analyses. The transition from die flow to extensional flow of an annulus occurs over a distance comparable to the annular thickness. Considerable extrudate swell can occur with the flow rearrangement, and the final ratio of outer to inner radius can exceed that at the die despite a reduction in this ratio over the entire draw zone. Asymptotic "thin-filament" equations describe the flow beyond the region of flow rearrangement.

THURSDAY, MARCH 28

Session III, ASC Room 205, 10:45 a.m.

AN ENGINEERING STUDY OF THE THERMOFORMING PROCESS: EXPERIMENTAL AND THEORETICAL CONSIDERATIONS

Michael E. Ryan
Department of Chemical Engineering
State University of New York at Buffalo
Amherst, NY 14260

Abstract

The development of a mathematical model of the thermoforming process is discussed in detail for the case of an axisymmetric geometry. The analysis of the free deformation process, as well as the subsequent constrained deformation of the membrane upon contact with the mold surface, is described by assuming the deformation to be isothermal. The mold surface geometries include cylindrical, conical, and a flat horizontal surface. The membrane is assumed to adhere and not undergo any subsequent deformation upon contact with the mold surface. A Neo-Hookean elastic stress-strain relationship has been employed in order to predict the resulting shape and deformation of the membrane as well as the required inflation pressure. A dynamic analysis of the deformation behavior has also been developed by using both purely viscous and viscoelastic constitutive relations.

Session III, ASC Room 205, 11:15 a.m.

A POTENTIAL FLOW ANALOGY IN FLUID FILM STRETCHING

Susumu Kase and Kuniaki Inoue

Kyoto Institute of Technology
Sakyoku Matsugasaki, Kyoto 606, JAPAN

Abstract

Thin film of isothermal Newtonian fluids lying on the (x, y) plane can be extended without generating thickness nonuniformity when the film is initially uniform in thickness and the velocity field $v_x(x, y, t)$, $v_y(x, y, t)$ of stretching obeys the equations

$$v_x(x, y, t) = a(t)\, x + b(t)\, v_x^*(x, y)$$

$$v(x, y, t) = a(t)\, y + b(t)\, v_y^*(x, y)$$

where (v_x^*, v_y^*) is identical to the two dimensional potential flow that satisfies the Cauchy-Rieman equations in (x, y) coordinates while a(t) and b(t) are arbitrary time functions. Drawing on the knowledge of classical hydrodynamics a number of interesting and physically realizable flow fields of uniform film stretching can be predicted analytically by the above solution (v_x, v_y). It was also proved analytically that thickness uniformity is maintained in any axisymmetrical stretching as far as the film is uniform initially.

THURSDAY, MARCH 28

Session IV, ASC Room 120, 2:00 p.m.

THE INFLUENCE OF THE INTERFACE BETWEEN RUBBER METAL DURING PROCESSING

D.M. Turner
Avon Rubber
Bath Road Melksham
Wiltshire SN12 8AA England

Abstract

The Mooney viscometer which has been the main tool for evaluating the viscosity of rubber has a highly indented rotor and cavity. Rubber machinery has smooth surfaces. The TMS Rheometer, where the contact pressure between the rubber and the rotor and the surface condition of the rubber can be controlled, enables interface effects to be studied systematically, using both grooved and smooth surfaces.

Results have been obtained which suggest there are both dry and lubricated frictional effects operating. The latter are affected very dramatically by the inclusion of salts of fatty acids but a number of unsuspected ingredients and the nature of the steel alloy can also have effects.

Session IV, ASC Room 120, 2:45 p.m.

DIMENSIONAL CONTROL AND DIE DESIGN FOR PROFILE EXTRUSION

James F. Stevenson
GenCorp Research
Research Division
Akron, Ohio 44305

Abstract

Achieving accurate dimensions in profile extrusion requires the design and cutting of dies which give specified profiles for average operating conditions and procedures for online dimensional control which bring critical dimensions to their specified values as quickly as possible during startup and maintain them there during typical process upsets.

Process control procedures are based on the following methods for controlling classes (thickness vs. width, thick sections vs. thin sections) of extrudate dimensions: (i) Size control by adjusting line speed relative to extruder output rate. (ii) Shape control through swell by manipulating stock temperature. (iii) Shape control through local die flow by adjusting the die temperature.

The third method involves changing the local flow rate through certain sections of a profile die relative to other sections by changing the die temperature set point. Two mechanisms explain this effect. Thinner sections of the die are more sensitive to changes in the internal die wall temperature since a large fraction of the flowing material is inside the thermal boundary layer. For complicated dies, the internal die wall temperature can vary between sections since this temperature is determined by the relative resistance to heat transfer between internal die sections and the heat source.

THURSDAY, MARCH 28

Session IV, ASC Room 120, 3:45 p.m.

EXTRUSION OF ELASTOMERS

L.F. Ramos-DeValle and R. Ramirez-Vargas
Centro de Investigacion en Quimica Aplicada (CIQA)
Blvd. Ing. Enrique Reyna Hermosillo
Saltillo, Coahuila, Mexico 25100

Abstract

Extrusion is one of the most important forming operations in the rubber industry; and this is now accomplished by either the hot feed technique, with screws usually having L/D ratios between 4/1 to 6/1, or by the newest cold feed technique, with screws usually having L/D ratios between 15/1 to 20/1. Whether hot or cold technique, there are some rubbers which exhibit its own specific phenomenon during extrusion, for example, NR has a tendency for flow-induced crystallization; and there are some phenomena exhibited by most rubbers, for example, die swell and extrudate distortion. These phenomena depends on: shape and dimensions of the die; pressure and temperature in the die; and the rheological properties of the rubber compound. These latter properties can be modified by compounding; for example, most fillers especially carbon black decrease die swell and extrudate distortion, oils and plasticizers decrease viscosity, lubricants assist in reducing die drag promoting so a smooth surface, etc.

Session IV, ASC Room 120, 4:30 p.m.

FLOW PATTERNS IN ELASTOMERS AND THEIR CARBON BLACK COMPOUNDS DURING EXTRUSION THROUGH DIES

Chin-Yuan Ma
James L. White
Frederick C. Weissert
Avraam I. Isayev
Nobuyuki Nakajima
Kyonsuku Min

Polymer Engineering Center
The University of Akron
Akron, OH 44325

Abstract

A basic study of flow patterns in elastomers in the entrance region of a die has been carried out for various gum elastomers including emulsion and solution butadiene-styrene copolymers, polybutadiene and natural rubber. All exhibit streamline flow into the entrance with the exception of a cold mastication degraded natural rubber which gave evidence of vortices in corners. A study of the die with a sharp diverging region showed dead spaces for all the elastomers. Carbon black compounds all exhibited streamline flow in a 180° entrance angle die and stagnant regions in the sharply diverging die. Evidence based on marker motions is presented for slip in the elastomer compounds on the entrance region.

THURSDAY, MARCH 28

Session IV, ASC Room 120, 5:15 p.m.

RHEOLOGY OF POLYMER MELTS IN HIGH SHEAR RATE REGION

Hideroh Takahashi, Takaaki Matsuoka and Toshio Kurauchi

Toyoto Central Research and Development Laboratories, Inc.
Nagakute-cho, Aichi-gun
Aichi-ken, 480-11, Japan

Abstract

We developed a specially designed high shear rate rheometer by which the rheology of polymer melts for the shear rate up to 10^{6} sec^{-1} can be investigated. Two non-Newtonian regions and a transition or the 2nd Newtonian region were observed in the wide range of the shear rate up to 10^{7} sec^{-1}. The observed flow curves for various polymer melts are classified into three typical patterns. One is the flow curve represented by high density polyethylene in which the clear 2nd Newtonian region appears after the 1st non-Newtonian region. The second is the flow curve represented by polystyrene in which the "transition region" appears instead of the 2nd non-Newtonian region. The third is the flow curve represented by acrylonitrile-styrene copolymer which shows the in-between.

THURSDAY, MARCH 28

Session V, ASC Room 122, 2:00 p.m.

DYNAMICS, STRUCTURE DEVELOPMENT AND FIBER PROPERTIES IN HIGH-SPEED SPINNING OF POLYETHYLENE TEREPHTHALATE

G. Vassilatos, B.H. Knox and H.R.E. Frankfort

E.I. du Pont de Nemours Co.
Wilmington, DE 19898

Abstract*

An experimental study of the spinning of PET between 4,000 m/min and about 9,000 m/min was carried out. Measurements of birefringence, density, temperature and diameter along the spinline were obtained. Physical properties and structural characteristics of the yarn were also obtained. The high-speed spun yarn exhibits enhanced draw set-texturability and dyeability at the boil without a carrier. The tenacity of the yarn is comparable to that of mechanically drawn yarn, but its amorphous orientation is significantly lower. The dynamics of the spinline, including the "neck formation", as well as the similarities and differences between high speed spun and mechanically drawn yarns are critically discussed and explanations are proposed.

*The complete article can be found in High-Speed Fiber Spinning, Editors A. Ziabicki and H. Kawai, John Wiley and Sons, Inc. (to be published, March 1985)

THURSDAY, MARCH 28

Session V, ASC Room 122, 2:45 p.m.

STRUCTURE DEVELOPMENT IN MELT SPINNING POLYVINYLIDENE FLUORIDE FIBERS AND TAPES

Yimin Wang
Mukerrem Cakmak
James L. White

Polymer Engineering Center
The University of Akron
Akron, OH 44325

Abstract

A series of polyvinylidene fluorides of varying molecular weight have been melt spun to form fibers and tapes. These have been characterized with wide angle x-ray diffraction (WAXD), differential scanning calorimetry (DSC), birefringence and small angle light scattering (SALS). WAXD and DSC have detected both the α and β crystal structures in melt spun fibers with the relative amount of β form increasing with drawdown stress. WAXD and birefringence have been used to detect orientation in the fibers. Hermans-Stein orientation factors have been computed for the α-phase as a function of drawdown stress. Superstructure has been investigated using SALS. The mechanical properties of fibers have been determined with a tensile testing machine and correlated with orientation and spinline stress.

THURSDAY, MARCH 28

Session V, ASC Room 122, 3:45 p.m.

STRUCTURE DEVELOPMENT DURING HIGH SPEED MELT SPINNING OF FIBERS

Joseph E. Spruiell
The University of Tennessee
Knoxville, TN 37996

Abstract

Recent studies in our laboratory of structure development during high speed melt spinning of polypropylene, nylon 6 and polyethylene terephthalate will be reviewed. Emphasis will be placed on the effect of varying molecular weight and other resin characteristics on the crystallization rate and resulting structure developed. The similarities and differences between the three polymers will be discussed.

THURSDAY, MARCH 28

Session V, ASC Room 122, 4:30 p.m.

STRUCTURE FORMATION IN HIGH SPEED MELT SPINNING

Ken-ichi Katayama
Institute for Chemical Research
Kyoto University
Uji, Kyoto-fu, 611 Japan

The process of high speed melt spinning is discussed from two viewpoints. One is the mathematical simulation and the other is concerned with the structure formation during the process.

(1) In order to deal with complicated problems in high speed melt spinning such variables as temperature, stress, orientation, and crystallinity must be expressed as functions of both the distance from the central axis of the filament and that from the spinneret.

(2) A model is proposed for the structure formation during high speed melt spinning of PET. Polymer molecules are slightly oriented by extrusion through a die and will be disoriented almost completely in the region of die swell. Following this, molecules are again oriented during the elongational flow. Cooling of the filament from the surface generates the gradient of temperature and viscosity in the radial direction, causing stress concentration in the outer part of the filament. Therefore, a mesomorphic structure which appears under molecular orientation is first generated in the outer part of the filament. Then, the stress in the outer part exceeds the yield value of the structure, which triggers the neck formation. With a sudden increase in the molecular orientation through neck formation, almost instantaneous crystallization takes place forming the final fiber structure.

Session V, ASC Room 122, 5:15 p.m.

POLYETHYLENE-POLYCARBONATE BLENDS: COMPATIBILIZATION PHASE MORPHOLOGY AND MEASUREMENT OF ORIENTATION DEVELOPMENT DURING CAST FILM AND TUBULAR EXTENSION BY INFRA RED DICHROISM

S. Endo, K. Min, J.L. White and T. Kyu
Polymer Engineering Center
University of Akron
Akron, OH 44325

The phase morphology and polymer chain orientation in polyethylene-polycarbonate blends is investigated. A blend with a dispersed polyethylene phase was found to exhibit phase growth under quiescent conditions. Addition of a styrene-(ethylene/butene) block copolymer controls the phase morphology and prevents phase growth. Melt spun tapes and tubular film have been prepared from polyethylene-polycarbonate blends. Orientation of the crystallographic axes of the polyethylene and the chain axis of the polycarbonate were determined by infra red dichroism. The addition of polycarbonate to polyethylene is found to decrease chain orientation at the same drawdown stress.

Session VI, ASC Room 205, 2:00 p.m.

FAST POLYMERIZATION AND CRYSTALLIZATION KINETIC STUDIES OF NYLON 6 BY COMBINED USE OF COMPUTERIZED MICRO-RIM MACHINE AND FT-IR

H. Ishida and C. Scott
Case Western Reserve University
Cleveland, OH 44106

Abstract

Reaction injection molding may be used to produce Nylon 6 parts from ε-caprolactam. A computerized Micro-RIM machine has been designed and built specifically for Nylon 6 RIM. The machine was designed for precise injection of reacting material into analytical instruments and for molding of samples for mechanical testing. It is capable of both two component and one component RIM. The amount of monomer injected may be varied continuously between 0.04 g and 150 g. The Micro-RIM machine and Fourier Transform Infrared Spectroscopy have been used to study the reaction kinetics of a unique one component RIM system. The monomer was polymerized using sodium hydride catalyst and phenyl acetate, a thermally activated initiator. This formulation allowed the catalyzed and initiated system to be stored at 80°C without significant reaction. The initiation reaction did not proceed to a significant extent until the material was injected into a hot mold. Shrinkage of the material during crystallization resulted in debonding from the prism of the IR cell. The coincident loss of optical contact provided a distinct spectral marking of the material shrinkage.

Session VI, ASC Room 205, 2:45 p.m.

MOLDABILITY DIAGRAMS FOR REACTION MOLDING

I. Manas-Zloczower* and C.W. Macosko
University of Minnesota
Department of Chemical Engineering
and Materials Science
Minneapolis, MN 55455

Abstract

Reaction injection molding or RIM is the high speed production of polymer parts by quick injection of low viscosity reactive monomers or prepolymers into complex shape cavities. The trial and error approach, mostly employed in production nowadays, reflects the state of art of this relatively new process. Obviously, material and process parameters determine the "moldability" of a specific system in a particular application. The concept of "molding areas" on the critical parameters plane can be extended from thermoplastic injection molding (TIM) to reaction injection molding (RIM). The finite element method was used to solve the equations governing both the filling and curing stages of the process. These moldability diagrams are intended to give first guidelines for process optimization as well as directions for starting new materials and new mold cavities.

*Present address: Department of Macromolecular Science, Case Western Reserve University, Cleveland, OH.

Session VI, ASC Room 205, 3:45 p.m.

REACTING POLYMER PROCESSING

J.M. Castro*
Chemical Engineering Department
Universidad Nacional del Sur
Bahia Blanca, Argentina

ABSTRACT

From the processing point of view, reacting processes can be classified into continuous and cyclic. Of the cyclic processes, the one that has developed the most is reaction injection molding (RIM).

In the present work, the differences and similarities between continuous and cyclic processes will be contrasted. The application of rheology to the analyses of reactive processes will be discussed. Some novel ideas for continuous processes will be presented. In particular, the technical feasibility of a continuous process to coat metalic conductors using reacting polymers will be discussed. The prediction of the mathematical model developed show that a feasible process can be designed by adequate control of the heat transfer phenomenon.

*Present Address: GenCorp Inc.
Research Division
2990 Gilchrist Road
Akron, Ohio 44305

Session VI, ASC Room 205, 4:30 p.m.

FLOW CHARACTERIZATION OF GROWING POLYURETHANE FOAM

W. Kostrzewski and J.T. Lindt
Department of Metallurgical and Materials Engineering
University of Pittsburgh
Pittsburgh, PA 15261

ABSTRACT

The apparent shear viscosity of a growing flexible PU foam has been measured under adiabitic conditions in flow fields associated with:

- free foam rise in an open cylindrical mold
- restricted capillary flow
- creeping flow past a sphere

The results suggest that viscous forces tend to dominate the flow. The experiments cover a range of shear rates 10^{-3}–10^{3} s^{-1}. Pronounced "shear thinning" effects have been found indicating some sensitivity of the terminal cell structure to the processing history of the foam.

THURSDAY, MARCH 28

Session VI, ASC Room 205, 5:15 p.m.

STATE OF THE ART OF THERMOSET TRANSFER MOLDING

Richard C. Progelhof
Plastics Processing Laboratory
New Jersey Institute of Technology
Newark, New Jersey 07102

ABSTRACT

The successful molding by the transfer molding process is dependent upon the initial condition and history of the resin charge placed in the transfer pot, the control of the transfer ram velocity, the geometric design of the runner/gate/cavity system and processing conditions. The interrelationship of these various parameters on molding is the subject of this paper.

Session VII, ASC Room 120, 9:00 a.m.

MIXING IN LAMINAR FLOW

L.F. Erwin
Massachusetts Institute of Technology
Department of Mechanical Engineering
Cambridge, MA 02139

Abstract

This will be a discussion concerning the recent advances in the understanding of mixing in laminar flow and its application to polymer processing. The dependence of mixing on deformation will be reviewed. Simple experiments illustrating the mechanism of mixers will be presented. Techniques for prediction of the performance of continuous mixers will be discussed and examples of simulation of a single screw extruder with mixing sections and static mixers will be shown. Extensions of the current understanding to mixing of rheologically non-homogeneous systems and to turbulent flows will be discussed.

Session VII, ASC Room 120, 9:45 a.m.

INTENSIVE MIXING IN COROTATING DISK PROCESSORS

L.N. Valsamis, G. Donoian
Farrel Company
Emhart Machinery Group
Ansonia, Connecticut

and

Z. Tadmor*
Department of Chemical Engineering
Stevens Institute of Technology
Hoboken, N.J. 07030

Abstract

The dispersion of solid additives into a liquid matrix in the corotating disk processor is studied experimentally and theoretically. Existing dispersion models are adapted to the corotating disk geometry and flow conditions. The effect of recycle over the channel block on dispersion efficiency is analyzed. Optimal mixing pin sequence configurations are proposed, and pass distribution functions over high shear regions, are derived.

*Permanent address:
Dept. of Chemical Engineering
Technion, Haifa, Israel

FRIDAY, MARCH 29

Session VII, ASC Room 120, 10:45 a.m.

THE RELATIONSHIPS BETWEEN MIXING AND PROPERTIES OF FILLED POLYMERS

Biing-Lin Lee
The BFGoodrich Company R and D Center
Brecksville, OH 44141

Abstract

The increased utilization of polymer blends and reinforced polymeric blend composites has prompted renewed interest in the relationships which can explain the properties of these materials in terms of the characteristics of mixing, and the concentration of components. As a first step toward developing the rules for multicomponent systems, we restricted our attention to two-component systems with particulate inclusions embedded in a continuous matrix. The following property-mixing relationships will be discussed: (1) reinforcement in the glassy state and in the rubbery state; (2) reinforcement of uncured and cured rubber composites; (3) elastic modulus, and thermal expansion of polymer composites; (4) elastic modulus, and thermal conductivity of polymeric foams; (5) heat build-up of rubber composites; and (6) electrical conductivity of polymer composites. Some important concepts and principles which have evolved from our experimental attempts at correlating the behavior of heterogeneous multiphase polymer materials will also be discussed.

Session VII, ASC Room 120, 11:30 a.m.

EXTRUSION OF MICA POLYPROPYLENE EXTRUDATE SURFACE TEXTURE

B. Remillard and B. Fisa

National Research Council Canada
Industrial and Materials Research Institute
75 de Mortagne Blvd., Boucherville
Quebec, Canada J4B 6Y4

Abstract

Extruded objects made of polymers filled with relatively large anisometric particles such as flakes or fibers usually exhibit unacceptable surface appearance. The surface texture is determined by the orientation of the reinforcing agent in the polymer matrix. In this work, the surface roughness of mica filled polypropylene was studied using laboratory extruder equipped with a variable thickness slit die. It was found that best surface was obtained whenever the extruder was operated in the starve feed mode. Probably causes of this surprising phenomenon will be discussed. Effect of other variables on flake orientation and surface roughness will also be described.

Session VIII, ASC Room 122, 9:00 a.m.

STRUCTURE OF POLYMERS DURING PROCESSING

Robert J. Samuels
School of Chemical Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0100

Abstract

The primary trust of all manufacturing processes is to fabricate a product with the most diserable end-use properties at the least cost. To do this most effectively, one should know the material structures that must be produced to yield the desired end-use properties. Only when such structural criteria are available can the most economically efficient process to produce those properties be rationally pursued.

The basic thesis of the present paper is that structural knowledge of a material is a necessary criteria for organizing process and property variables into a logical and systematic form, and that rapid nondestructive techniques should be available to characterize these structures. Examples will be given of the application of some new nondestructive techniques to characterization of isotoctic polypropylene processing.

Session VIII, ASC Room 122, 9:45 a.m.

STRUCTURE DEVELOPMENT IN SIMULTANEOUS BIAXIALLY STRETCHED AND ANNEALED POLYETHYLENE TEREPHTHALATE FILMS

M. Cakmak
J.L. White
Polymer Engineering Center
The University of Akron
Akron, OH 44325

and

J.E. Spruiell
Department of Materials and Science and Engineering
University of Tennessee
Knoxville, TN 37916

Abstract

Polyethylene terephthalate (PET) films and bottles are being used for various packaging applications. This polymer can be obtained in totally amorphous or largely crystalline (60%) forms depending on the processing history.

In this paper, we present a detailed study of structure developed in unequal and equal films were characterized with various techniques: Density Column, Differential Scanning Calorimetry, Wide and Small angle X-ray Scattering, Abbe Refractometer and tensile testing. The structure developed in various modes of stretching (uniaxial constant width, unequal and equal biaxial) are described and crystallinity and phenyl plane orientation developed are correlated with optical properties.

FRIDAY, MARCH 29

Session VIII, ASC Room 122, 10:45 a.m.

A STRUCTURE-ORIENTED MODEL OF INJECTION MOLDING

M. Kamal
Department of Chemical Engineering
McGill University
Montreal, Canada

Abstract

Traditionally, computer simulation of plastics injection molding has emphasized the analysis of the thermo-mechanical history of the material during the filling stage. Thus, models have been useful in establishing the moldability envelope for the material. These models are usually based on simple consideration, and many simplifying assumptions can be made without loss of utility.

In many cases, it is necessary to obtain a more complete and detailed modelling of the behavior of the polymer throughout all the stages of the process. Particularly, it would be of interest to obtain relevant information regarding the microstructure (crystallinity, morphology, orientation, frozen stresses) and alternate mechanical and optical properties of the molded article (tensile properties, birefringence, etc.). For this purpose, it is essential to obtain a simulation of all stages of the process (filling, packing, and solidification) and to incorporate a more detailed description of material behavior (visco elasticity, crystallization kinetics, etc.). A structure-oriented model and some of the results obtained with it will be presented.

Session VIII, ASC Room 122, 11:30 a.m.

STUDY ON ULTRA HIGH SPEED SPINNING - STRUCTURE FORMATION OF FIBERS

Jiro Shimizu
Tokyo Institute of Technology
Textile and Polymeric Materials
O-okayama, Meguro-ku
Tokyo, Japan

Abstract

Ultra high speed spinning has been promoted as a new way of future production system of man-made fibers. We have been investigating the high speed spinning of PET, PP, Nylon 6, 66 and I2, etc. and we have made clear the properties, the formation of structure of these polymers by ultra-high speed spinning. The results can be summed up as follows. Molecular orientation, increases with increasing of take-up velocities. Crystallization started at a certain value of molecular orientation. We can observe a neck-like deformation along the spin-line. We believe that the structure of the spun fibers was developed through such deformations.

FRIDAY, MARCH 29

Session IX, ASC Room 205, 9:00 a.m.

DYNAMIC SIMULATION FOR INJECTION MOLDING OF THREE-DIMENSIONAL PARTS WITH GRAPHICS

V.W. Wang and K.K. Wang

Cornell University
Mechanical Aerospace and Engineering
Ithaca, NY 14853

Abstract

A detailed formulation is presented for simulating the injection-molding filling of thin cavities, together with the delivery system, in three-dimensions. The modelling is based on the generalized Hele-Shaw flow for an inelastic, non-Newtonian fluid under non-isothermal conditions, which has been previously proven to be satisfactory for simulating the polymer melt flow in the cavities. A hybrid numerical scheme is employed in which the injection molded part is described by two-dimensional triangular elements, provided that cavity thickness is relatively thin, and the gapwise and time derivatives are expressed in terms of finite differences. The elements are flat, but can have any orientation in 3-D space to approximate the surfaces of the molded part.

Session IX, ASC Room 205, 9:45 a.m.

PRESSURE EFFECTS ON RHEOLOGICAL BEHAVIOR OF MELT POLYMERS --A DISCUSSION IN RELATION TO POLYMER PROCESSING

K. Oyanagi and K. Kubota
Kogakuin University
Nishishinjuku, Shinjuku-ku
Tokyo 160, Japan

Abstract

Polymers have large bulk compressibility in the molten state, and their rheological properties are largely affected by pressure applied in polymer processing. The volumetric strain induced by the pressure consists of an instantaneous and a retarded elastic strains, both of which are proportional to the pressure, and recover reversibly on removal of the pressure. In many crystalline polymers, as observed by Maxwell for polyethylene, the retarded elastic strain in large, and it is mostly due to pressure crystallization.

This paper describes results of experimental studies relating pressure effects on rheological properties of melt polymers with polymer processing and bulk properties of the products. following items are discussed; pressure-induced shear stress, analysis of local deformation pattern, critical shear stress for melt fracture, relation between power-law index and bulk compressibility, effects of hydrostatic pressure on melt flow behavior, pressure efficiency of injection molding, jetting phenomena, shrinkage in injection molding, residual strain, and high pressure injection molding process.

FRIDAY, MARCH 29

Session IX, ASC Room 205, 10:45 a.m.

SIMULATION OF COMPRESSION MOLD FILLING FLOW

Ching-Chih Lee* and Charles L. Tucker III

Department of Mechanical and Industrial Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801

Abstract

The interaction between heat transfer and flow through temperature-dependent viscosity during compression molding of a cold charge in a hot mold is studied by numerical simulation of two-dimensional cases. The finite element method is used to solve the equations of motion and energy with a mesh which conforms at every instant to the shape of the charge. The results show that a thin layer of warm, low viscosity fluid at the mold surface lubricates the remainder of the charge, which undergoes nearly a planar elongation deformation. For typical material properties and operation conditions of compression molding of sheet molding compound, very little preferential flow of the material near the mold surface is predicted. The results support the assumption of a flat velocity profile in nonisothermal compression molding, and explain the success of some isothermal mold filling models at predicting mold filling patterns for nonisothermal cases.

*Present Address: GenCorp Inc., Research Division,
2990 Gilchrist Road, Akron, OH 44305

Session IX, ASC Room 205, 11:30 a.m.

RECENT DEVELOPMENT IN THE INJECTION MOLDING OF POLYMERS

A.I. Isayev
Polymer Engineering Center
The University of Akron
Akron, OH 44325

Abstract

Theoretical and experimental investigations of the various aspects of mold filling, packing and cooling in injection molding of polymers have been considered. Development of frozen-in orientation and stresses have been discussed in terms of flow and thermal-induced birefringence and stresses. Development of shrinkage has been discussed in terms of volumetric changes during molding. The nonlinear viscoelastic formulation has been developed to predict frozen-in flow stresses and birefringence and development of the solidified thermal boundary layer during nonisothermal flow. The linear elastic and viscoelastic formulations have been employed to describe thermal stresses. The equation of state incorporated into dynamic equations of cavity filling has been used to predict shrinkage. Solutions to these problems have been obtained by numerical techniques. A variety of molding and quenching conditions and cavity geometries have been employed, and the effects of processing parameters have been determined and compared with the predicted results.

FRIDAY, MARCH 29

Session X, ASC Room 120, 1:30 p.m.

THE OPTIMISATION AND CONTROL OF INTERNAL MIXING

Philip K. Freakley
Institute of Polymer Technology
University of Technology
Leicestershire, LE11 3TU, England

Abstract

The internal mixing operation is a complex, none steady-state multivariable process, in which strong interactions between process variables influence both productivity and the quality and uniformity of mixed batches. Methods of quantifying the combined influence of process variables on process performance are essential for understanding the internal mixing operation; and form an integral part of process optimisation procedures. Methods used commonly in current control systems to estimate the 'state of mixedness' and hence determine when control actions should be initiated and mixing terminated are mixing time, batch temperature and mixing energy. They are indirect indicators, in that they do not involve measurement of a critical physical property of the material being mixed; and it can be shown that relationships between these indicators and the properties of mixed batches are influenced by the levels of other process variables. To overcome this problem, methods of control have been developed, for both fixed- and variable-speed mixers, which involve determinations of the mixer drive torque at reference rotor speed and batch temperature; and drive torque is taken to be directly proportional to batch viscosity.

Session X, ASC Room 120, 2:15 p.m.

FLOW VISUALIZATION OF ELASTOMERS IN AN INTERNAL MIXER

Kyonsuku Min
James L. White

Polymer Engineering Center
The University of Akron
Akron, OH 44325

Abstract

The dynamic motions of elastomers and plastics followed in an internal mixer with a glass window ere using a video system. The behavior of the major elastomers including natural rubber, polybutadiene and emulsion and solution butadiene-styrene copolymers as well as molten plastics, specifically low density and high density polyethylene melts, have been investigated. The influence of mixer fill factor, rotor speed and material temperature was followed. Severe tearing was observed in most of the elastomers except the natural rubber. The same materials showed a stagnant region over the bridge under the ram. This increased notably with increasing fill factor.

FRIDAY, MARCH 29

Session X, ASC Room 120, 3:00 p.m.

RHEOLOGICAL PROCESSES IN MIXING CARBON BLACK AND RUBBER

J.L. den Otter
TNO
P.O. Box 71
2600 AB Delft
The Netherlands

Abstract

Mixing carbon black and rubber is a rheological process, governed by flow and friction properties over a large range of temperatures. The flow and friction properties were found to depend not only on the temperature, but also on the deformation history. For a description of the mixing process, it is necessary to define the degree of mixing, a number of techniques were developed to obtain a physical measure of the degree of mixing.

Session X, ASC Room 120, 3:45 p.m.

MECHANISM OF MIXING IN AN INTERNAL MIXER

N. Nakajima
Polymer Engineering Center
The University of Akron
Akron, OH 44325

Abstract

Traditional treatment of the mixing mechanism in an internal mixer is based on a laminar, shear flow model with attending data of steady state viscosities as a function of steady state shear rate.

This approach contradicts with rotor-design, which is intended to give non-steady deformation rates as the material is moved around inside of the mixer. Further, it ignores viscoelastic nature of elastomers and polymer-melts, which exhibit transient, non-steady response. The deformation mode is not restricted to shear, but more importantly large extension is involved. The extension is so large that it often results in fracture of the material. This is particularly true with elastomers.

FRIDAY, MARCH 29

Session XI, ASC Room 122, 1:30 p.m.

A FUNDAMENTAL STUDY ON FOAM EXTRUSION

C.D. Han
Department of Chemical Engineering
Polytechnic Institute of New York
Brooklyn, NY 11201

Abstract

Presentation will be given on our recent investigation of foam extrusion of low-density polyethylene and polystyrene. For the study, fluorocarbons were used as blowing agent, and an annular die was used to produce biaxially oriented cells in foam sheet. Emphasis will be placed on relating the effects of processing variables (e.g., melt temperature, blowing agent concentration, take-off speed) on foam extrusion characteristics, namely, foam density, tensile modulus, and cell morphology. Also, the effect of the rheological properties of polymers on foam extrusion characteristics will be discussed. Finally, the importance of the understanding of the phenomena of bubble nucleation and bubble growth will be pointed out for successful operation of foam extrusion processes.

Session XI, ASC Room 122, 2:15 p.m.

POLYSTYRENE FOAM SHEET EXPANSION DURING HEATING

J.L. Throne
Amoco Chemicals Corporation
Naperville, IL 60566

Abstract

Although amorphous materials such as PS have broad thermoforming temperature ranges and large draw ratios, the equivalent low density closed cell foams have very restricted ranges and very low draw ratios. During heating of low density PS foam sheet, expansion occurs owing to increasing cell gas pressure and decreasing cell wall strength. Excessive heating rates can lead to catastrophic cell collapse. This work examines the nonisothermal mechanics of foam sheet expansion and compares the results with experiments. It is found that a proper heating model uses a thermal conductivity that includes conduction and radiation to optically thick materials. The internal cell gas pressure model is simple adiabatic expansion of an ideal gas and a strutless membrane cell structure model works well.

FRIDAY, MARCH 29

Session XI, ASC Room 122, 3:00 p.m.

ON THE EXTRUDABILITY OF POLYETHYLENES UNDER SIMILAR PROCESSING CONDITIONS

A.M. Catani and L.A. Utracki
Industrial Materials Research Institute
National Research Council of Canada
75, Boul. de Mortagne, Boucherville
Quebec, J4B 4Y4 Canada

Abstract

The three types of commercial HDPE, LDPE and LLDPE resins were extruded at 190°C through a laboratory, ϕ=3.2cm, extruder equipped with a slit or a rod die. The rotational speed of the screw varied from zero to 90 RPM. Extrusion pressure, output and energy were measured and correlated with the rheological parameters of the resins, measured under steady state, as well as dynamic and extensional modes of deformation.

The extruder output was found to depend on the method of feeding and the restriction on the die. For highly restrictive slit die the shear modification of high molecular weight LDPE was observed.

Session XI, ASC Room 122, 3:45 p.m.

MODELLING OF EXTRUSION DUE FLOW AND APPLICATION TO DIE DESIGN

Horst Henning Winter
University of Massachusetts
Amherst, MA 01003

Abstract

In the first part, an overview of the most important features of die design will be given: flow rate as a function of pressure drop, distribution in large aspect ratio extrusion dies, shaping and extrudate swell, melt fracture, slip flow, heat transfer, flow induced orientation. In the second part, two design aspects will be discussed in greater detail: the distribution problem and flow induced orientation in annular extrusion dies. We will emphasize the basic phenomena and their importance for the overall design of extrusion dies.

FRIDAY, MARCH 29

Session XII, ASC Room 205, 1:30 p.m.

STUDIES ON DRY SPINNING OF POLYURETHANE-UREA ELASTOMERS: THEORY AND EXPERIMENTS

H. Ishihara, K. Tani, S. Hayashi and H. Ikouchi
Toyobo Company Ltd.
2-1-1 Katata
Otsu, Shiga
520-02 Japan

Abstract

Numerical computations of the fundamental equations for dry spinning were carried out for various spinning conditions of the polyurethane-urea elastomers. Solutions obtained give the steady-state dry spinning behaviors such as spinline cross sectional area, spinline temperature, spinning tension, spinline deflection and solvent concentration profile within a filament, as a function of the distance measured downward from the spinneret point. Dry spinning experiments were conducted for the polyurethane-urea/dimethylformamide system. The variables of spinning conditions were changed mainly in terms of throughput, take-up speed, ambient air temperature and so on. It was found that the residual solvent concentration and the spinline deflection show good agreement with the prediction from the computations. The stress-strain properties and molecular orientations of as-spun fibers were investigated to obtain a relationship between the fiber properties and the out-put variables from computations.

Session XII, ASC Room 205, 2:15 p.m.

COMPATIBILITY AND WATER RETENTIVE PROPERTIES OF POLYACRYLONITRILE COPOLYMER AND POLYVINYL ACETATE COPOLYMER BLEND FABRICS

F. Li, J. Qin, Z. Liu, Z. Wu and B. Qian
Man-Made Fiber Research Association
East China Institute of Textile Science and Technology
Shanghai, P.R. China

Abstract

A series of blend fibers of polyacrylonitrile copolymer (PAC) and poly(acrylonitrile-vinyl acetate) (PAVAc) or poly-(vinyl acetate) (PVAc) were prepared by mixing the polymers in suitable solvents followed by wet spinning. These blend acrylic fibers have a microporous structure that renders them highly water-retentive. The PAC/PAVAc blends will change from homogeneous phase state to phase separation as the vinyl acetate content in PAVc copolymers increases; the critical composition of PAVAc lies between 12.4 and 19.7 wt% VAc. We also concluded that: (1) phase separation takes place in all porous blend fibers; (2) not all the incompatible polymer blend pairs can be made into highly porous, water retentive fibers (i.e. PAC/PAVAc5). Consequently, phase separation is only a necessary condition for pore formation but not a sufficient condition. It still depends on the following factors: (i) During wet spinning, the disperse phase must coagulate first; and coagulated disperse phase must contract more than the continuous phase, causing interfacial creviees. (ii) The existence of voids in the continuous phase also contributes to water retention.

FRIDAY, MARCH 29

Session XII, ASC Room 205, 3:00 p.m.

RHEOLOGICAL PROPERTIES OF MELT-POLYMERIZED ALIPHATIC AROMATIC COPOLYAMIDES

Tsutomu Sugie
Unitika Ltd.
Research and Development Center
Kyoto, Japan

Abstract

In order to obtain a new type of copolyamide with improved mechanical properties, Nylon 66-PT copolymers (P ; p-phenylene-diamine, T ; terephthalic acid) were prepared by melt polycondensation. These copolyamides substituting of Nylon 66 up to 30 mole% of comonomers were subjected to the measurements such as melting temperature (Tm), glass transition temperature (Tg), melt viscosity (μ) and dynamic and static mechanical properties (G^*,σ-ε). Characteristics of the copolyamides are also compared with those of molecular composites on blending aramid (PT) prepared by solution polymerization with aliphatic polyamide (Nylon 66). Nylon 66-PT were easily melt-processable and solid materials have a good heat stability. The copolyamides show the non-Newtonian behavior having smaller values of N than Nylon 66 approximately expressed by $\tau \propto \dot{\gamma}^N$ (τ ; shear stress, $\dot{\gamma}$, shear rate), which is attractive to plastic extrusion processing at high or low $\dot{\gamma}$ with high fluidity and high dimensional stability of extrudate. The effect of aromatic ring, introduced into polymer backbone, adjacent to amide group and aromatic amide unit of PT result in higher value of Tg and modulus of the newly synthesized aliphatic-aromatic copolyamides.

Session XII, ASC Room 205, 3:45 p.m.

AN EXPERIMENTAL APPROACH TO THE STUDY OF HIGH SPEED PET SPINNING

X. Hu, G. Wu, F. Li and B. Qian
East China Institute of Textile Science and Technology
1882 West Van-an Road
Shanghai, China

Abstract

We are able to get on-line spinning parameters and to characterize the solidification process of a melt-spun filament. Several interesting findings can be noted. We discovered that when a 235 den, 36 filaments PET-preoriented yarn was spun at a winding speed of 3500m/min. the filament temperature at a distance of 120 cm from the spinneret was found to rise abruptly from 82°C to 91°C, and maintain itself constant up to the lubricating point. This is apparently an evidence of isothermal crystallization induced by stress-orientation. The spinning line stress at the point where induced crystallization begins is around 6x10 dyne/cm and the corresponding temperature 91°C. We discovered that spinline necking can also be promoted by reducing the pump feed of the melt, i.e., spinning of finer denier filaments. We came to realize that occurence of necking is governed not only by the magnitude of stress alone but by a suitable combination of temperature and stress. Above a certain temperature the filament can be drawn by gradual thinning without necking. The sufficient conditions for necking are: at a point on the spinning line both the temperature must be low enough and the stress high enough for necking to occur; otherwise only gradual thinning will occur at a point higher up the line.

FRIDAY, MARCH 28

Closing Lecture, ASC Room 120, 5:00 p.m.

DISPERSIVE MIXING OF CARBON BLACK IN RUBBER

Z. Tadmor

Department of Chemical Engineering
Stevens Institute of Technology
Hoboken, N.J.

ABSTRACT

The mechanisms of carbon black dispersion in rubber will be analyzed and discussed. A theoretical formulation of agglomerate breakup in shear fields will be outlined, some non-Newtonian effects discussed, and the notion of Pass Distribution Functions over high shear regions, in batch and in continuous mixers will be introduced. A theoretical formulation of an internal "Banbury" type batch mixer will be presented. The model predicts particle size distribution as a function of mixing time and it yields a new scale up criterion. Finally, some of the open questions of the dispersive mixing problem will be discussed.