Spring 1996 Meeting Abstracts

ABSTRACTS OF PAPERS PRESENTED AT

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NONWOVENS COOPERATIVE RESEARCH CENTER 3RD ANNUAL CONFERENCE

May 13 - 15, 1996, Nassau Inn, Princeton, New Jersey 08542

"Polyolefin Fibers by Solid State Forming"

Roger S. Porter

University of Massachusetts, Amherst, Mass. 01003

Several high-molecular weight polyolefins and vinyl polymers have been uniaxially drawn from different initial morphologies by four techniques: solid-state extrusion, rolling, tensile drawing and their sequential combinations (two-stage drawing). These polymers include UHMW-polyethylene, iso-polypropylene, and iso-poly(4-methyl-1-pentene). Among these, solution-grown single crystal (SGC) mats of UHMW-PE, PP and P4M1P could be ultradrawn to extreme values in terms of mechanical and physical properties approaching their theoretical limits. Practical processing of reactor powders and the useful properties of these three polymers will be emphasized and compared with the properties of other polymers.

"Thermoplastic Fibers Reinforced with Thermotropic Liquid Crystalline Polymers"

Donald G. Baird

Virginia Tech, Blacksburg, VA 24061-0211

This presentation is concerned with a process for generating thermoplastic fibers reinforced with thermotropic liquid crystalline polymers(TLCPs), the associated properties of the fibers , and some possible applications. The novel process is based on plasticating the matrix and the TLCP in separate extruders and then passing the two streams through a static mixer under controlled residence times to form a single stream consisting of many continuous fine streams of the TLCP embedded in the matrix. The stream is then passed through a spinneret to form fibers which are drawn to orient the TLCP phase. The properties (strength and stiffness) of the fibers indicate that there is a synergistic effect as those of fibers containing a 50/50 ratio of matrix and TLCP, for example fibers based on a 50/50 volume ratio of PET and a TLCP, can be quite similar to those of the neat TLCP. Because the TLCP can have a melting point higher than that of the matrix, the fibers can be processed to form composite structures without disrupting the order within the TLCP phase.

"Advances in High Performance Specialty Fibers"

G. Farrow

Hoechst Celanese Corporation, Charlotte, NC 28232-2414, USA

Hoechst Celanese Corporation (a wholly owned subsidiary of Hoechst AG, Frankfurt, Germany) manufactures(in most cases) and markets a number of high performance specialty fibers. An up to date overview will be given of four of these products, namely PBI, Vectran®, Certran® and Trevar®. These are respectively a polybenzimidazole fiber, an aromatic polyester fiber based on thermotropic liquid crystal polymer technology, a high molecular weight melt-spun polyethylene fiber and an aramid fiber. Generally more than one form is available, possessing different properties. The talk will concentrate on the attributes of these fibers and their various applications.

"Aramid/Inorganic Hybrid Fibers"

Kiu Seung Lee

E.I. DuPont de Nemours, Richmond, VA 23261

In spite of their inherent thermal stability, high temperature organic fibers such as Nomex® and Kevlar® have a definite limitation in temperature resistance versus inorganic fibers such as glass and carbon. A step change improvement in flame resistance, as measured by LOI, has been achieved by creating hybrids between aramids and certain transition metal oxides. Hybridization techniques include: 1) sol-gel reaction of transition

metal halides and, 2) imbibition of polymetalates from the solution. Possible mechanisms involved in the polymer/transition metal interaction will be discussed.

"A Unique One Step Process of Achieving Fully Oriented Yarn Properties with <1500 m/min Take-Up Speed"

T.Y. Tam and C.Y. Lin

Allied Signal, Petersburg, VA 23804

A continuous process for spinning fully oriented polyamide-6 yarn using a liquid in-line drawing device at take-up speed <1500 m/min is discussed. With this in-line drawing device, the threadline dynamics including tension and temperature are judiciously controlled at a condition favoring the development of oriented molecular structure.

By applying this device, the drawn yarn properties were achieved in one-step process with a relatively low spinning speed(<1000 m/min), which normally can only be obtained through either a spin-draw process or higher spinning speed above 3500 m/min. Further increase of spinning speed, superior tensile properties of spun yarn were obtained as a results of the formation of a highly oriented a-crystalline structure in the morphology. Benefits of the process using the in-line drawing device are the formation of stable package at a low spinning speed, improved tensile properties, improved dimensional stability, and dye washfastness.

"Air Cooling of Synthetic Multifilament Yarns"

T. Charbonneaux, Nylstar, Cesano Moderno(MI);

R. Tasse and M.L. Riethmuller, Institut Von Karmann, Brussels

P. Barthelemy, Rhone-Roulenc, Courbevoie, France

Experimental measurements in wind tunnels have been carried out to get information on the boundary layer structure around a set of filaments : Laser Doppler Velocimetry (LDV) technique was used to measure the surrounding air velocity profiles, and Infra-Red Thermography was used to investigate the surface temperature of heated wires in a stream of air.

When the flow regime is still laminar, the velocity profiles in the external region of a set of multifilaments is exactly similar to the one recorded around an isolated single filament. In the internal region between 2 filaments, an intersection exists causing a pseudo-parabolic velocity profile. In the vicinity of each filament, flow and heat transfer remain axisymmetric.

When the interaction effect increases (the distance between filaments decrease or along filaments increase), there is a transition toward turbulent flow. This transition is well

characterized by the change of the velocity profiles or the convective heat transfer coefficients. In the vicinity of each filament, flow and heat transfer still remain axisymmetric. Increasing the number of filaments seem to facilitate the transition toward turbulence.

"A New Model of Non-Isothermal Crystallization for Modeling Melt Spinning"

Andrzej Ziabicki

Polish Academy of Sciences

Institute of Fundamental Technological Research

21 Swietokrzyska St., 00-049 WARSZAWA, Poland

A new model of crystallization kinetics in variable external conditions has been developed. The model concerns situations when external conditions (temperature, stress, pressure) changes in time. Compared to earlier models, the model includes transient and athermal effects, dependent on the rate of change of the external conditions. The model can be used for simulation of crystallization in fiber spinning and other industrial processes.

The early models of non-isothermal crystallization concerned only *quasi-static* variation of temperature, valid in the limit of slow cooling. In melt spinning, cooling rates may reach thousands degs/sec and such effects can not be neglected. Application of the model is illustrated with examples of polypropylene and polyethylene terephthalate.

"Structural and Mechanical Characterization of Fibers with Remote Laser Raman Microscopy"

Costas Galiotis

Queen Mary & Westfield College, Mile End Road, London E1 4NS

Laser Raman Spectroscopy (LRS) has been used for years for the structural characterization of polymers and to asses degree of crystallinity, degradation properties, etc. In this presentation, the application of this technique applied in the study of polymer fibers will be reviewed. With the use of flexible-optic cables for laser delivery and collection, Raman measurements can now be made on materials located at large distances (e.g. factory floor, storage places, etc.) from the Raman detector. This opens the possibility of using LRS as an industrial non-destructive technique in a variety of applications.

Extensive experimental Raman spectroscopic work on a series of high performance polymer and polymer derived fibers, has been undertaken at QMW over the last few years. The relative intensities and bandwidths of the first, as well as, the second- order

Raman spectra of these fibers have been related to variations in (a) crystallinity (b) surface treatment and (c) processing conditions. The molecular deformation of all these fibers has also been studied In detail by subjecting them to tensile or compressive stresses while monitoring their Raman response. Furthermore, the effect of temperature upon the Raman spectrum of these fibers has also been examined.

Liquid crystalline polymer (LCP) fibers, for example, appear to be quite brittle in tension while in compression they "yield" at relatively low levels of applied compressive strain. The differences in the slopes of the Raman frequency versus applied strain curves in tension and compression respectively, can be used to obtain good estimates of the compression moduli. Plots of modulu vs. appiled strain have been produced for a whole range of fibers. The observed trends are strikingly similar to chain modulus vs. strain graphs produced by *ab initio* quantum-mechanical calculations. Finally, a method of converting the Raman frequency versus strain data of LCP fibers into molecular stress-strain curves in both tension and compression, will be demonstrated.

"Investigation of Structural Evolution During the Melt Spinning Using On-Line SAXS-WAXS Techniques"

M. Cakmak

University of Akron, Akron, Ohio 44325-0301

As part of joint research between the University of Hamburg ITMC and University of Akron Polymer Engineering Institute, we have developed a remotely controlled melt spinning system at DESY polymer beam-line. With this system it is possible to SAXS and WAXS experiments at a series of locations along the spinline. This system consisting of an extruder, a metering pump and a take-up motor system was assembled on two separate stepper motor driven platforms. To investigate the structure development during crystallization, fiber location at the desired distance from the die could be positioned at the beam level with synchronous vertical movement of extruder and take-up platforms and small and wide angle X-Ray patterns can be taken simultaneously with two dimensional wire detector and image plate, respectively.

In this presentation, the results of the experimental studies that were performed on Polyvinylidene Fluoride and its blends with atactic Polymethyl methacrylate will be presented.

The data obtained for variety of take up speeds generally indicate that SAXS d-spacings first appear large in the early stages of crystallization and gradually along the spin-line(as the crystallization progresses). As the take up speed increases, the crystallization onset position moves away from the die and d-spacings observed at the onset increases. In addition, the shape of the discrete scattering pattern becomes teardrop shape with the tip of the teardrop pointing towards the beam stop at the onset of crystallization at high take up speeds. This indicates spread of distribution of d-spacings of oriented crystallites at the early stages. Our studies also indicated that SAXS patterns appear earlier than the

appearance of the wide angle crystalline diffraction peaks indicating that the significant ordering occurs in the melt prior to crystallization. Influence of processing conditions and blend composition will be discussed.

"Analysis of Structural Features of Significance to the Study of Diffusion Behavior in Nylon 6 Fibers"

N. Sanjeeva Murthy

Allied Signal, Inc.

Research and Technology, Morristown, New Jersey

With the availability of new measurement techniques and refinements in existing techniques, it is possible to study the structure of the fibers in greater detail, and use these results to develop a deeper understanding of the fiber properties. The results of our efforts along these lines will be illustrated using the data from nylon 6 fibers. We have been able to use the wide-angle x-ray diffraction data to identify and analyze the isotropic and anisotropic amorphous chain segments. Existence of a substantial fraction of unoriented amorphous chains has been substantiated by the recently obtained inelastic neutron scattering data. Since water diffuses only into the amorphous regions, we have been able to use D2O as a probe to study the partitioning of water into various types of amorphous domains. The results obtained from small-angle neutron scattering measurements on this hydrated nylon fibers have been complemented by deuterium NMR measurements. We have used commonly used parameters such as crystallinity, crystallite size and crystalline orientation to understand the mechanism of crystal growth during drawing and heat setting. The changes in lamellar and fibrillar organization that occurs during these processing steps have been studied using small-angle x-ray scattering techniques. Significance of these results to our understanding the glass transition behavior and the diffusion phenomena in fibers will be discussed.

"Solid-State Polymerization in Polyesters and Polyamides: Mechanism, Kinetics and Morphological Consequences"

S. Rangarajan1, S. Narayan2, R. Knorr3, P. Desai3, A. Abhiraman4

Polymer Education & Research Center

Georgia Institute of Technology, Atlanta, GA 30332

1Ciba-Geigy Corporation

2School of Textiles & Fiber Engineering

3Monsanto Fibers Technical Center

4School of chemical Engineering

This presentation examines some long-standing problems in solid-state polymerization (SSP) of polyesters and polyamides that can be addressed effectively through well established elementary principles. These pertain to:

- The Mechanisms that facilitate SSP and the corresponding kinetics (A "diffusion analog" of reaction-dictated migration of functionality will be introduced.)
- Morphological consequences of SSP
- Implications regarding post-extrusion SSP in filaments, including the initial morphological requirements for producing deformable structures
- The role of intrinsic molecular rigidity vis-a-vis evolution of order through SSP in oriented polyesters and polyamides

"Resilience Properties of Polypropylene Carpets"

L. Vangheluwe and P. Kiekens

Department of Textiles (Universiteit Gent)

Technologiepark 9, B 9052 Zwijnaarde, Belgium

Resilience of carpets means their ability of recovery after a load being applied on the carpet surface. Lack of resilience is a serious problem for woven and tufted carpets with polypropylene pile yarns. Up till now, resilience can only be measured on the carpet itself. Although it is known that the constructional characteristics and the properties of the pile yarn influence the resilience of carpets, little is known about the effects of the separate parameters.

The paper discusses results obtained with static loading tests applied on simulated carpets. The developed carpet simulation method allows to study the influence of the pile yarn and the influence of carpet constructional characteristics on the resilience of tufted carpets. Results will show the impact of pile density, pile height and cross over on the resilience. Furthermore, the influence of the pile yarn will be illustrated.

The Department of Textiles has been working on the development of a test method to measure the resilience of the pile yarn without the need of tufting a carpet ar even making a carpet simulation. Two methods will be presented with which it is expected to measure aspects of the relevant yarn properties. Some preliminary results will be shown which indicate a promising future for the test methods for direct measurement on yarn itself. These methods will make quality control and the development of polypropylene pile yarns

easier, faster and less expensive.

"Anisotropy in the Mechanical Properties of Fibers"

Sueo Kawabata

Department of Materials Science

The University of Shiga Prefecture, 2500 Hassaka Hikone 522 Japan

Fibers have a strong anisotropy in their mechanical properties due to the highly oriented micro structure along the longitudinal direction of the fiber. An explanation of the details of the fiber properties is now needed to further understanding of the fiber properties and micro-structure from the scientific point of view and also for the precise design of fibrous materials and fiber reinforced composites from the engineering side. In order to precisely observe the fiber property, a direct measurement system of single fiber, "Micro measurement", was developed recently by the author, and fiber data for various fibers covering a range from apparel to high performance fibers are being accumulated. In this presentation three topics will be presented from recent investigations conducted by the author. First, the anisotropy in the elastic modulus of fibers are introduced as well as an introduction of the measurement system. Then, the result of the anisotropy in the viscoelasticity of Aramid fibers is introduced. These results provide us with a key for presuming the micro structure of Aramid fibers. Finally, the anisotropy in the failure of fibers, especially the failure in the longitudinal torsion and longitudinal compression, are introduced as well as the fatigue behavior in the torsion. With respect to the fiber fatigue caused by repeated torsion, a relation of the g-N equivalence (g: strain amplitude, N: number of loading cycles) has been found. This relation of the time-temperature equivalence in the viscoelasticity of amorphous polymers is a powerful tool for the prediction and design of the fatigue life of fibers.

"Predicting the Knotting Performance of Surgical Sutures"

Tao Hong1, Martin W. King1,3, Randolph P. Guzman2

and Robert Guidoin3

1Dept. of Textiles & Clothing

2Dept. of Surgery, University of Manitoba

3Quebec Biomaterials Institute, Laval Univ., Quebec, Canada

If one refers to the U.S. Pharmacopeia to determine the required standards for surgical sutures, one finds that the only apparent properties of interest are the suture's diameter and knot pull strength. For these two properties the limits for each size of suture are clearly specified, and the test methods described. However, from a surgeon's point of view there

are a number of other important criteria that must be considered when deciding which type and size of suture to use. These include more esoteric characteristics, such as ease of handling and ease of knot formation, as well as tissue drag and the performance of the knot itself.

The main objective of this study was to determine how this knotting behavior is influenced by the mechanical properties and surface characteristics of braided and monofilament sutures. It was therefore first necessary to develop a series of valid test methods that would enable us to reliably measure on an Instron Universal Tester certain knot characteristics, such as knot security, knot run-down and knot snug-down. Then a series of different sizes of braided and monofilament sutures were tested for their knotting performance, as well as their tensile and bending properties using standard test methods, their dry and wet tissue drag, and their surface characteristics, such as friction and roughness, using Kawabata Evaluation System.

Correlation analysis was performed so as to determine which suture properties can be used to predict knotting performance. As expected both knot pull strength and knot security correlated closely and positively with suture diameter, tensile strength , and to a lesser extent, with bending stiffness. On the other hand, knot run-down and knot snug-down were influenced both positively and negatively by a number of size related, tensile and surface characteristics, depending on whether a braided or monofilament suture was being tested.

This study has been successful in improving both the measurement techniques and our understanding of certain psychophysical characteristics of sutures that are used by surgeons as selection criteria. While such characteristics still have to be more precisely defined and measured, the results of this study will, nevertheless, assist manufacturers in engineering more clinically acceptable sutures.

"Bending Fatigue of Carbon Fiber Reinforced Epoxy Composite Strands"

Rebecca Couillard and Peter Schwartz

Cornell University, Ithaca NY 14853-4401

The bending fatigue behavior of unidirectional, continuous, carbon fiber/epoxy composite strands was characterized. The fibers used were PAN-based carbon fibers(AS4, Hercules Inc.). The matrix was bisphenol-A based(DER 331, Dow Chemical Co.) cured using a pentamine hardener(DEH 26, Dow Chemical Co.). The coated fibers were sized using a circular die(Ø= 0.5 mm), yielding a composite with 3K fibers and a fiber volume fraction of 0.43.

The strand was subjected to two-way bending at 3 Hz. A radius of curvature of 11.1 mm was imposed on the fiber, producing an initial surface strain of 0.0225. Fatigue damage was measured by a loss of flexural rigidity.

Damage occurred by fiber breakage, matrix cracking, and interfacial failure. At high number of cycles, there was crack growth in the matrix along fiber interfaces.

In tests up to 106 cycles, the decay in flexural rigidity follow an exponential rule. No strands failed after 106, nor was a fatigue limit reached. It is, however, hypothesized that for greater number of cycles, crack growth would continue to decay exponentially until the surface strain fell below the failure strain of the outermost fibers, at that point the strand would reach a fatigue limit. At 3 Hz, this was calculated to occur after approximately 5.8-1018s.

"Finite Elements for Yarn Mechanics"

Wayne A. Munro

De Montfort University, Leicester, U.K.

A new approach to the application of finite elements to aligned fiber assembly problems is introduced. This more rigorous application of finite element analysis will allow the solution of problems which have been impossible to solve using previous approaches. Difficulties with nonlinear material properties and large scale deformations are overcome by defining the element stiffness matrix in a coordinate system based on the energy modes of the element deformation. The transformation of the element properties back to a conventional coordinate system to allow assembly of all the elements in the structure is presented.

A finite element is developed using this approach to model three dimensional aligned fiber assembly problems, and is used to model a hypothetical singles yarn under various deformations.

"Elongational Rheology of Polymer Melts in Converging Dies"

Ajit V. Pendse and John R. Collier

Louisiana State University, Baton Rouge, LA 70803

Application of lubricated converging flow technique on a commercial capillary rheometer to determine the elongational viscosity of polymer melts was presented by the authors earlier. This paper presents the results of extending the strain rates to commercially relevant values for industrial grade polymer melts of polypropylene, syndiotactic polystyrene and nylon-66. It is shown that polypropylene and sPS melts show strain softening whereas the nylon-66 melts show a strain hardening behavior at intermediate strain rates (1-2 s- 1). A correlation of molecular weight distribution with the elongational viscosity is apparent but more work is needed to establish definite trends.

Experiments with single layer extrusion of surfactant materials through hyperbolic dies shows that a modified Cogswell's method could be developed. A technique using a single

layer extrusion would simplify the measurements as it will obviate the need to use a suitable skin material that must be two orders of magnitude lower in viscosity than the core, immiscible with the core, and should be stable at the flow conditions.

"Dynamic Mechanical Studies of Nylon 66 Fibers in Water/Glycerol Baths"

Hawthorne Davis

North Carolina State University, Raleigh NC 27695-8301

With improved understanding of the fiber microstructure differences which lead to dye streaks as a goal, a method was developed for measuring dynamic mechanical properties of nylon (or other) fibers in mixtures of water and glycerol. The assumption was that quantifying the effect of the chemical activity of water on the a transition would increase understanding of the free volume processes which enable dye diffusion in semicrystalline fibers. As might be expected, the atransition moved to lower temperatures with increasing water in equilibrium with the fiber. Quantification of this effect was somewhat involved because the bath was an open system, i.e. some water evaporated while the test was being run. To obtain dynamic mechanical responses for constant water/glycerol mixtures, the glycerol content of the bath was monitored at different temperatures in a time-scheduled test, and a polynomial interpolation scheme was implemented. The results were interpreted with a method [1], which derives a mobile, noncrystalline fraction, X, and an internal viscosity, h, from tan d and G. For a wide range of water fraction and temperature, h behaved like the viscosity of an Eyring liquid. Also, over a wide range of temperature and water fraction, X was linear with mol fraction water in the bath, a parameter which to a first approximation would represent the chemical activity of the water.

Citations

Davis, Hawthorne, Advances in Fibre Science, Ed. S. Mukhopadhyay, The Textile Institute, 1992, Chapter 7.

"The Microstructure of the Transcrystalline Region in Fiber-Reinforced Polypropylene Composites"

D.M.Dean, R.A. Register, L.Rebenfeld,

TRI Princeton and Department of Chemical Engineering

and

B.S.Hsiao, DuPont Central R & D.

Certain fiber-matrix pairs produce an unusual polymer crystalline morphology along the fiber surface. This "transcrystalline" morphology is the result of dense nucleation at the fiber at the fiber surface which leads to anisotropic growth of the crystalline phase. We examine the molecular and lamellar orientations of this transcrystalline region in fiber-reinforced isotactic polypropylene (PP) by synchrotron-based simultaneous wide-angle (WAXS) and small-angle (SAXS) x-ray scattering on model composite specimens. Pitch-based carbon fibers produce a strong orientation of the PP unit cell and crystalline lamellae, while Kevlar-29® fibers produce a qualitatively similar but less oriented structure. However, glass-reinforced PP show a gualitatively different orientation of the PP unit cell than that obtained in the pitch and Kevlar-29® composites. An epitaxial mechanism, combined with the known "lamellar branching" phenomenon in PP, is used to explain the nucleation and growth of the observed transcrystalline microstructure.

In addition, differential scanning calorimetery (DSC) was used to obtain information regarding the isothermal crystallization kinetics of the composite systems. It was observed that reinforcing fibers increase the crystallization rate of the PP matrix.

"In-Plane Movement of Liquids Through Curved Fabric Structures"

H. L. Friedman, TRI/Princeton, NJ 08542

Forced in-plane flow of liquids through continuous flat and curved regions is being studied both as general phenomenon and for predicting the flow of polymers during injection molding of monolithic composite structures with complex configurations. Cells have been fabricated to encapsulate a fabric along a path that is first vertical, then curved, and finally horizontal, or vice versa. A controlled pressure difference is applied to drive the flow. Flow rate is measured gravimetrically by Liquid/Air Displacement Analysis(LADA). Fluid flow equations have been adapted for analyzing the flow in the flat sections, leading to the evaluation of permeability constants and capillary pressures. A saturated flow rate measured at constant hydrodynamic pressure is used to evaluate the overall permeability coefficient of the encapsulated fabric. Results obtained with several fabrics indicate that permeability can be reduced as a consequence of flow through the curved region.

"Automated Image Acquisition and Analysis For Single Fiber Composite Testing"

S.P.Wesson, J.N.Walker and R.Johnson

TRI/Princeton, Princeton, NJ 08542

A.Netravali

Cornell University, Ithaca, NY 14853

R.Parnas

National Inst. of Standards and Tech., Gaithersburg, MD 20899

Single fiber composite testing is widely used for evaluating interfacial and environmental effects on fiber/matrix adhesion. A single fiber is embedded in a dogbone shaped specimen of polymer that is strained incrementally until the number of fiber breaks in the gauge length is constant. The conventional apparatus consists of a set of grips, driven manually by a loading screw, that is placed on a motorized microscope state. The operator strains the specimen in the grips, then obtains an image of the fiber on videotape as the stage moves horizontally under the microscope lens. A computer program for measuring fiber fragment lengths interactively from video recordings has been described in the literature. The process of straining the specimen repeatedly, videorecording the fiber and obtaining the fiber fragment distribution is a laborious and time-consuming procedure. We present an apparatus for automating the interfacial shear strength experiment. The TRI apparatus for automating interfacial shear strength measurements consists of four components; an actuator that strains the specimen; a computer camera and microscope lens mounted on a three-axis positioner; a computer, and a program that conducts the experiment, then analyzes the results.

"Evaluation of a Ballistic Fabric"

Y.K. Kamath, K.R. Ramaprasad, and H.D. Weigmann

TRI/Princeton, P.O. Box 625, Princeton, NJ 08542

H. Kuhn

Milliken Research Corp., Spartanburg, SC 29304

An attempt has been made to evaluate the properties of Kevlar® aramid fabric which may be relevant to its ballistic behavior. Properties such as yarn pull-out force, along with tensile shear and bending properties of the fabric have been determined. The yarn pull-out force, which is directly related to interfiber friction seems to play a significant role in the ballistic behavior. All the properties mentioned above decrease when the fabric is treated with poly(pyrrole) to improve its electrical conductivity. When the ballistic tests were carried out with the fabric mounted in a square frame with the warp and the fill along the diagonals, the fabric always opens along the warp diagonal. It is likely that this is due to the high speed shearing of the fabric under ballistic impact. Possible mechanisms of energy dissipation which can improve the ballistic resistance of the fabric will be discussed.

"Writing Performance - The TRI Pen Line Evaluator"

Bernard Miller, Sheldon P. Wesson, Jo N.Walker, Robert A.Johnson

TRI/Princeton, Princeton, NJ 08542

A means for obtaining a continuous record of line quality produced by a pen or marker is described. The instrument obtains digital images using a computer/camera combi-nation operating in a mode that makes it possible to monitor a moving line. Image analysis algorithms produce a record of line width and intensity that can quantify changes in writing performance with extent of usage.

"The Influence of Resin Variables on the Structure and Properties of Melt Spun Polypropylene Filaments"

J.E. Spruiell, F.M. Lu, Z. Ding and G.C. Richeson*

University of Tennessee, Knoxville, TN 37996-2200

* Exxon Chemical Co., Baytown, Texas 77522-5200

Isotactic polypropylene (iPP) is used extensively for spunbonded and melt blown nonwovens applications. Variables influencing the choice of iPP resin for such applications will be discussed. In particular, the influence of average molecular weight, polydispersity, isotacticity, ethylene comonomer content, and nucleating agent additives will be described and discussed.

"Conditions That Effect the Loss in Fabric Strength Using Cellulases in Denim Garment Washing"

Geoffrey Weiss, Dennis McEwan, Mee-Young Yoon

Genencor International, South San Francisco, CA 94080

Cellulase enzymes are in wide use for denim garment finishing to improve softness and to impart a fashionable "worn" look. The use of cellulase enzymes has allowed the recuction, and in some cases the elimination, of pumice stones which has improved the environmental impact and the overall economics of the process. Along with the benefits of using cellulase enzymes in this application, some users have noticed a decrease in the tensile and tear strength of the treated garments.

In a lab scale washer, the process variables of temperature, pH, enzyme dose, and washing time were studied by monitoring the tensile and tearing strength, as well as the degree of "stonewashing" effect of the test garments. Various commercial cellulase products as well as laboratory preparations of purified cellulase components were used in these experiments.

"Influence of Fiber Structure on Properties of Thermally Point Bonded Fabrics"

Rahul Dharmadhikary, Veratec, Walpole, MA 02081-1898

Hawthorne Davis, Thomas Gilmore, Subhash Batra,

North Carolina State University

A point bonded fabric is a network of fibers, bonded in discrete regions called bond points, by application of heat and pressure. Though the point bonding process is simple, a clear understanding of the properties of point bonded fabrics is not available. There is also a lack of information about the ideal fiber structure required for point bonding and the changes in fiber structure/properties on bonding.

A detailed study of fiber properties such as, stress-strain characteristics, crystallinity, radial orientation, molecular weight distribution, melt flow rate, dynamic mechanical properties of two widely different fiber types (T-196 and T-101) is carried out and their influence on point bonding evaluated. The fiber strength/elongation loss and severity of flaws introduced after bonding depends mainly on bonding temperature. T-196 fiber has a sheath-core structure which helps in the formation of a "non-failing" bond at 149oC as compared to T-101 fiber which can be bonded only at 160oC. This minimizes damage to T-196 fiber structure and consequently the fabric strength is higher. Other characteristics which are related to the bonding behavior are the melting onset region and the dynamic modulus.

"Supercritical Fluid Technology Applied to Textile Fiber Applications"

Paul D. Seemuth

DuPont Nylon, Chattanooga, TN 37415

Supercritical fluids offer many unique physical properties that allow new and interesting applications for textile areas. Supercritical fluids provide the textile industry with a good environmentally safe replacement for chlorosolvents that are used for many analyses. Supercritical fluids are generally gases under atmospheric pressure and temperatures. Under supercritical conditions, these liquids can display a wide range of solubility characteristics with liquid-like densities. With the supercritical fluids generated from gaseous precursors, zero surface tension, gas-like diffusivity/viscosity properties offer enormous potential for use of the supercritical state.

Supercritical Co2 provides an environmentally friendly solvent system offering flexible solubility parameters based on T and P conditions. Investigations have been undertaken to examine the unique properties of CO2 for use in textile fiber applications. Replacement of chlorosolvents in finish-on-yarn (FOY) analyses can be readily accomplished using supercritical carbon dioxide. Studies have shown that most lubricant and surfactant

processing aids can be readily extracted from a synthetic fiber matrix with little difficulty. High polarity materials can be extracted either with modification of the temperature /pressure conditions or via modifier use. Most synthetic fibers' finish systems can be analyzed via this method without the environmental problems associated with standard chlorosolvent methods.

Additional discussion will outline the design of an on-line SFE-FTIR method for quantifying FOY without solvent waste. Other analysis methods under testing with this prototype SFE-FTIR include nylon moisture, oligomer analyses, and trade problems related to processing aids and polymer additives. Other potential uses of supercritical fluids as applied to textile fiber's arena will be covered.

"Using Laser Scanning Confocal Microscopy to Evaluate Fabrics"

Karen K. Leonas,

The University of Georgia, Athens, GA 30602-3622

There has been little reported on the use of confocal microscopy to evaluate textiles, however potential capabilities of this technique are of interest. The primary advantage of this type of microscopy is the ability to discriminate optical planes of the sample. Instead of the entire field being illuminated and magnified as a complete area, as is done in conventional compound microscopy, the specimen is scanned by a finely focused beam or simultaneous array of beams. By manipulation of the each individual plane image, a three dimensional image of the fabric section can be achieved. Other proposed advantages of confocal microscopy techniques include the capabilities for non-invasive serial section, high resolution epi-fluorescence, high resolution sectional imaging, and non-destructive examination of surface topography.

This paper will address various techniques used in preliminary studies using Laser Scanning Confocal Microscopy to qualitatively examine the pore structure of fabrics and the transmission mechanism through fabric structures.

"Polyurethane Membranes For Protective Clothing: Dynamic Contact Angles and Rate Effects"

Pauline Ukpabi and S. K. Obendorf

Cornell University, Ithaca, New York 14853

We modified Pellethane 2363-80A membrane surfaces by incorporation of surface fluorine and studied the wetting properties of both treated and untreated membranes using a Wilhelmy balance/friction apparatus which we recently acquired from TRI, Princeton, NJ. Preliminary data indicated that the advancing contact angles for the untreated membranes were rate dependent and increased with increasing platform velocity between

0.0003 and 0.0021 cm/sec (correlation of 83% between contact angle and platform velocity). the receding contact angles, on the other hand, were not so strongly dependent on rate and seemed to level off as the rate increased. Hysteresis increased with speed and also seemed to level off at higher velocities. preliminary data also indicated that platform travel might be important in contact angle studies on films and membranes. Data will be presented on both treated and untreated membranes focussing on the effects of platform travel and platform velocity on the dynamic contact angles of the polyurethane membranes.

"Measuring the Fundamental Adsorption and Aggregation Properties of Commercially Available, Unpurified Surfactants: Results for Quaternary Ammonium Surfactants"

Timothy J. Taylor and Andrew D. Cook

Reckitt and Colman Tehcnical Center, Montvale, New Jersey 07645

Measurements of the fundamental properties of com-mercially produced surfactants are usually complicated by the presence of surface active impurities. We have developed techniques for removing the effects of such impurities from the plots of surface tension (g, measured by the Wilhemy Plate method) vs log10C (common logarithm of the concentration) for commercially available quaternary ammonium surfactants (quats), without purification of the materials. Thus, we calculated the critical micelle concentrations (cmc) and areas-per-headgroup (ao) directly. In commercial quats, the surface active impurities appear as unreacted amines and amine-HCI salts. Beyond the normally seen minima in g vs log10C plots of commercial surfactants, we found that these impurities caused pronounced scatter in the data, especially at low concentrations. By lowering the pH to 2 and aspirating the surfaces of the solutions just before measuring g, we obtained curves with virtually no scatter or minima, and calculated the cmc and ao values directly from the plots. For comparison, we also report here results from our measurements of "pure" quat samples with chemical structures similar to the commercial materials. Measured cmc and aO values for the commercial quats are in excellent agreement with our results for the "pure" quat samples and all our experimental results agree well with literature values for these and other quats.

"An Opto-Electronic Device for Online Measurement of Fiber Orientation and Twist of Threads"

M.S. Bradshaw, P.G. Schliachtenko* & Y.N. Vetrova*

De Montfort University, Leicester England LE1 9BH

*St. Petersburg State University of Technology and Design,

St. Petersburg, Russia

The specific angular orientation of fibres in fibrous materials, such as paper and non-wovens, is often of paramount importance. It is well known that the orientation distribution contributes directly to isotropy of strength and elasticity, and has a direct influence upon the optical reflection, thermal transmittance, fluid flow, and other essential characteristics. Controlling the orientation of the individual fibres during production is possible with modern machinery, but measuring this parameter is highly problematic, and currently performed by an inspector counting and recording fibre orientations from a sample under a microscope. The time lag between measurement and feedback of results can often lead to much sub-standard production.

This paper describes a low cost opto-electronic method for measuring the isotropy of fibre orientation that is based on measuring the optical reflective properties of fibrous materials. As only the reflective properties are used, non-transparent materials may be analyzed, giving a broad range of application from wood sheets to textiles. The hardware is electronic, giving results in real time. It may be used off line on static samples or on line on a moving web, and recent variants are now operational in the paper and pulp industry.

An extrapolation of the use of this device is to measure the twist of threads using the same principle. The twist in a thread imparts important characteristics such as strength, durability and reliability of use. Its measurement is traditionally performed using a mechanical twister /untwister, but as with the measurement of fibre orientation, this is a laborious, purely offline method requiring the destruction of isolated samples of thread. An alternative to this is long overdue, as is a method for measuring the twist online without the need for interrupting a production process. This is a new application of the methodology, and initial experimental results are presented.

It is envisaged that a device based on this methodology could be used online for control, as a portable hand held unit for monitoring the slippage of spinning spindles, or as a bench mounted laboratory instrument.

"Introduction to the Innovative Rotor-Doubling Twister"

I-Shou Tsai, Jia-Horng Lin

Feng Chia University, Taichung, Taiwan, R.O.C.

Although the ring twister and the two-for-one twister have been introduced for many years, the productivity is still limited owing to the constructional design and the twisting tension. Today, the production is within 19~28 m/min (8000rpm~12000rpm) for the ring twister and 19~65 m/min (4000rpm~14000rpm) for the two-for-one twister. In general, the physical properties of the plied yarns produced by the two-for-one twister are not as good as those by the ring twister. This paper introduced the working principles of a novel twister of our own design -- a super-high-speed-rotor-doubling twister and the basic comparisons between the novel twister and the radical twisters e.g. the variance of tension, the CV% of twisting, the percentage loss of the twist, the yarn strength and the yarn elongation. At present, the rotation speed of the novel rotor-doubling twister is over

30,000 rpm that are equal to about 70 m/min in production. The experimental results show that the rotor-doubling twister shows a lower or equal twisting tension than the ring twister, and the physical properties of the plied yarns of the rotor-doubling twister are better than those of the ring twister and the two-for-one twister under the constant twisting conditions.

"The Wet Comfort of Small Disposable Incontinence Pads"

Alan Cottenden1 , Grahams Dean1, Rodney Brooks2

and Pat Thorburn3

1Dept. Medical Physics & Bioengineering, University College

London & Dept. Geriatric Medicine,

St. Pancras Hospital, London, WCIE 6JA, England

2Dept. of Statistical Science, University College London

3Dept. of Geriatric Medicine, St. Pancras Hospital, London

The wet comfort of small disposable incontinence pads was studied by testing batches of experimental pads engineered to have a range of absorption capacities and wet back properties. After some preliminary work to decide which materials combinations to select, and to pilot clinical testing, a panel of twenty women (aged 37 - 89) living in the community were asked to test three pad variants. Variant F combined high absorption capacity with good wet back properties while variant A had poor absorption capacity and poor wet back properties. Variant C fell between the two.

Two experiments were run. Experiment 1 used a single-blind design in which testers were each supplied with a random mix of 42 pads comprising 14 of each of the three (unlabelled) and variants to use in a numbered sequence. They were asked to log the time at which they put on and took off each pad and, when they took a pad off, to score it for leakage performance, wet comfort and absorbance using a three point scale (Good, OK, Bad). In addition they were asked to save pads in individual plastic bags for subsequent weighing. In this way, the impact on wet comfort of a range of variables could be studied.

In Experiment 2, testers were asked to use each of the pad variants for a week in turn and, at the conclusion of the second and subsequent weeks, to declare whether the wet comfort and overall performance of this week's pad were greater, about the same as, or less than that of last week's.

As predicted by the absorption capacity and wet back properties of the pad variants, clinical testing generally ranked wet comfort in the order F better than C better than A. However, none of the differences in clinical performance was very large considering the

substantial differences in absorption capacity (factor of 2 between F and A) and wetback (factor of 30 between F and A). Indeed, many differences failed to achieve statistical significance. When testers were asked to compare the wet comfort of pairs of pad variants having tried each in turn for a week, they generally ranked them in the same order (F>C>A) as emerged from experiments with intermingled C pads. However, none of the differences was statistically significant.

Overall, the improvement in wet comfort achieved by a substantial increase in absorption capacity and reduction in wet back were disappointing. However, differences were often big enough to be noted and appreciated by some testers.

"Relation Between Fiber Breakage and Length Properties of Cotton"

Kearny Q Robert,

Southern Regional Research Center,

New Orleans, Louisiana, 70179

Fiber length has been universally recognized as one of cotton's most important properties. Length is a principal basis for cotton's processing quality, yarn strength, and product quality. Therefore, length is a major determinant of its market value. With the advent of scientific tools in this century, it became possible (although arduous), to sort fiber by length, to measure objectively the length distribution, and to calculate various statistical properties of length. Classing of cotton in the U.S. has recently been converted from manual to high-volume-instrument (HVI) technology. HVI systems provide extremely rapid instrumental measurements, including length information. Although these statistical length properties are very useful in grading, the structure of the cotton fiber length distribution has not been understood previously. Recent research on cotton fiber breakage during mechanical processing has revealed a new understanding of the fundamental nature of phenomena which generate the length spectrum, and the mathematical description of the resulting shape of the distribution. This allows the detailed investigation of cotton fiber length properties reported here. It is assumed that the length distribution of cotton fiber can be modeled as the results of breakage mechanisms acting upon an ideal ("paragon") distribution, which is Gaussian by mass. The shape of the length distribution then is manifested as a member of a specific family of curves. It is shown that simple breakage statistic called length quality, or "Q", can be used to index the degree of intactness of the fiber length distribution. Q is defined as the mass fraction of unbroken fibers. Most cottons produced in the U.S. fall into the range from Q = 40% to Q = 60%. Computer simulations are performed for a wide range of breakage intensities and cotton genotypes. Relationships between the damage intensity indexed by Q, and conventional statistics such as mean length, upper-quartile length, upper-half-mean length, uniformity index, mass uniformity, coefficient of variation, and short fiber content are explored. The results are used to establish the fundamental theoretical relationships between breaking damage, the shape of the fiber length distribution, and the impact of breakage on statistical properties. An understanding of these principles is crucial to the practical

optimization of processing machinery and technology for achieving preservation of the quality of cotton fiber length.

"Formaldehyde-Free Zein Fiber -- Preparation and Investigation"

Yiqi Yang1, Liming Wang2, and Shiqi Li3

1Monsanto Company, P.O. Box 97 Gongalez, FL 32560,

2Auburn University and3Georgia Institute of Technology

A novel dry spinning method for the preparation of zein fiber without using formaldehyde is presented. The fiber thus obtained had good stability to boiling aqueous acetic acid solution with breaking tenacity and elongation of 12.0 g/d and 30%, respectively. Citric acid and butanetetra-carboxylic acid were used as nonformaldehyde crosslinking agents for the preparation of zein fiber successfully. Using polycarboxylic acids have advantages such as no toxicity and low sensitivity to the variation of processing conditions over formaldehyde containing stabilizers. The effects of crosslinking before and after stretching on improvement of fiber properties will be discussed. Fiber morphological structure was also examined by means of wide angle x-ray diffraction and sonic velocity.

"Mechanics of Needlepunching Process and Products: Study of Forces Experienced by Individual Needles During Needlepunching"

Abdelfattah M. Seyam and Asaad S. Mohamed

Nonwoven Cooperative Research Center,

College of Textiles, NCSU

Raleigh, NC

A novel integrated system to on-line monitor the dynamic forces acting on individual needles at different locations in the needle board in a needle loom, to acquire these forces, and analyze the collected data has been developed. The system components (the force transducer and its mounting arrangement, the data acquisition system, and the data analysis systems) are briefly presented.

Statistical experimental designs were conducted to study the influence of needlepunching processing parameters (loom speed, needling density, needle penetration, and needle position in the needle board) and needled fabric weight on peak stripping forces and peak penetration forces. The results show that the processing parameters and their first, second, and third order interactions have significant effect on the peak stripping forces and peak penetration forces.

RETURN TO LIST OF PAPERS PRESENTED AT SPRING 96 MEETING

Spring 1996 Meeting Abstracts