



# THE SOCIETY OF RHEOLOGY 72<sup>ND</sup> ANNUAL MEETING

Westin Resort  
Hilton Head Island, South Carolina  
February 11-15, 2001

## Symposium PO Poster Session

Organizer: Susan J. Muller

Monday 5:30 Savannah Foyer North PO1

### **ELONGATIONAL VISCOSITY MEASUREMENTS OF POLYMER MELTS USING SEMIHYPERBOLIC CONVERGENT DIES**

**Parag D. Patil, Simioan Petrovan, and John Collier**

Chemical Engineering Department, University of Tennessee - Knoxville, Knoxville, TN 37996

Elongational rheology of polyethylene melts of different molecular characteristics is studied using the Advanced Capillary Extrusion Rheometer (ACER) by Rheometric Scientific<sup>TM</sup>. The polymeric material for this work includes five samples each of low density polyethylene (LDPE) and high density polyethylene (HDPE), having different molecular weight, molecular weight distribution, and melt flow rate. The elongational flow is generated by replacing the capillary die in the ACER by a semihyperbolic convergent die. The effective elongational viscosity of polyethylene melts is estimated from the measurement of pressure drop across the die and the knowledge of die geometry. The effective elongational viscosity of polyethylene melts is dependent upon molecular characteristics, i.e. weight average molecular weight, branching content and catalyst effects. The effective elongational viscosities of polyethylene melts at different Hencky strains and temperatures are shifted to a general master curve. A generalized equation is developed for the effective elongational viscosity of a LDPE melt as a function of elongational strain rate, Hencky strain, and temperature. The influence of molecular characteristics on the shift factors is under investigation.

Monday 5:30 Savannah Foyer North PO2

### **TRANSIENT AND STEADY THREE-DIMENSIONAL DROP DEFORMATION UNDER ELONGATIONAL FLOW**

**Y.T. Hu**

Unilever Research, Edgewater, NJ 07020

The time evolution and steady state of a droplet in an immiscible liquid under elongational flow was investigated. An imaging system employing two cameras and a derivative-edge-detection technique was developed to obtain the contour and deformation of the drop simultaneously from two perpendicular views in real time. After flow startup, the time evolution of the drop deformation can be described by an exponential growth function in the limit of small deformation. After flow cessation, the drop deformation can be described by an exponential relaxation function up to rather large deformation. Both the transient and steady-state drop shapes fit very well to an ellipsoid with three different axes up to the critical breakup deformation except for drops with very low viscosity ratios, in which case the shape deviates from the ellipsoid when pointed ends develop at high capillary numbers.

Monday 5:30 Savannah Foyer North

PO3

**HIGH PRESSURE CAPILLARY VISCOMETER****Eric J. Paul<sup>1</sup>, Robert K. Prud'homme<sup>1</sup>, Sheldon P. Wesson<sup>2</sup>, and Ross Clark<sup>3</sup>**<sup>1</sup>Chemical Engineering, Princeton University, Princeton, NJ 08544; <sup>2</sup>Ynir Instrumentation Software, Princeton, NJ 08540; <sup>3</sup>Biopolymers R&D, Monsanto, San Diego, CA 92123

A pressure driven capillary viscometer has been constructed to measure the rheological properties of water soluble polymer solution such as guar or dextran at high shear rates. The viscometer is designed around a fixed volume cell that is filled with fluid and pressurized with a small amount of nitrogen. After pressurization, the cell is isolated from the high-pressure nitrogen source. A computer initiates the flow of the fluid through the capillary and collects pressure data from a transducer and mass data from an analytical balance, both as a function of time. As the fluid flows out of the cell the driving pressure decreases, and since the computer can collect the data at high rates, we are able to collect useful data as the pressure changes. Once the raw data is converted to viscosity versus shear rate, our design allows for over a decade in shear rates to be measured in a single experimental run. The instrument is designed to work with capillaries as small as 0.010" ID and nitrogen gas pressures as high as 2500 PSI. This combination of pressure and capillary size allows viscosity measurements to be made at shear rates in excess of 500,000 s<sup>-1</sup> for typical concentrations of guar.

Monday 5:30 Savannah Foyer North

PO4

**KINKS VS. CURVES: AN EXAMINATION OF THE SLOPE DISCONTINUITY IN CAPILLARY FLOW****Montgomery T. Shaw<sup>1</sup> and Edwin M C. Cua<sup>2</sup>**<sup>1</sup>Dept. of Chem. Eng. & Polymer Prog., Inst. of Materials Sci., University of Connecticut, Storrs, CT 06269-3136; <sup>2</sup>Polymer Program, Institute of Materials Science, University of Connecticut, Storrs, CT 06269-3136

A curious aspect of melt flow through a capillary is the apparent coincidence of a sudden change of slope in the flow curve with the onset of sharkskin melt fracture at high stress. In view of this coincidence, it has been suggested by several that sharkskin melt fracture is the result of a different flow regime, at least near the capillary wall. In this study we examine this issue in detail, using both actual data and data synthesized from realistic GNF functions. The basic technique was to formulate a statistic (e.g., similar to  $\chi^2$ ) that reflects the difference between comparable kinked and curved descriptions of the synthetic data, and derive the distribution function for the statistic. This distribution was then assumed to hold for the real data. It was found that kinks are rare.

Monday 5:30 Savannah Foyer North

PO5

**IN-LINE RHEOMETRY OF SHEAR-THINNING AND SHEAR-THICKENING COMPLEX FLUID SYSTEMS BY UVP-PD METHOD****Peter Fischer<sup>1</sup>, Jeelani Skaik<sup>1</sup>, Boris Ouriev<sup>2</sup>, and Erich J. Windhab<sup>1</sup>**<sup>1</sup>Laboratory of Food Process Engineering, ETH Zurich, Zurich 8092, Switzerland; <sup>2</sup>Buehler AG, Uzwil 9240, Switzerland

The in-line investigation of the rheological properties of complex fluids is based on the superposition of a Pressure Difference measuring method (PD) with the Ultrasound Velocity Profile method (UVP). The method uses a high frequency ultrasonic beam that is emitted into the flow field to be investigated. The signal is scattered by tracer particles in the flow and the time delay and the frequency shift between emitted and received pulse is determined. This shift, known as the Doppler shift, is related to the speed and the direction of the moving scatterers. The shape of the obtained velocity profile together with the pressure drop is used to calculate the rheological properties, i.e. the flow curve of the sample. Conventional process rheometers are in general not suitable to accurately measure in-line rheological properties because of their "invasive" nature that may cause non-rheometric conditions. Also these methods may create severe bio-safety problems due to contamination. In the presented study concentrated, non-transparent model suspensions that exhibit shear-thinning, shear-thickening, and time dependent properties under pipe flow condition were investigated. The obtained in-line flow curves are compared with data from conventional rotational rheometers. In the case of the shear-thinning suspension both in-line and off-line viscosity functions fit extremely well. For the shear-thickening suspension, however, the dilatant flow effect is more pronounced in the

flow curve obtained by the in-line technique. We relate this feature to the different characteristics of the drag and pressure driven flow fields. Consequently, the UVP-PD method can be used for non-invasive measurement of complex fluids as concentrated suspensions within given accuracy.

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PO6

**SHEAR-BANDING STRUCTURE ORIENTATED IN THE VORTICITY DIRECTION  
OBSERVED FOR EQUIMOLAR MICELLAR SOLUTION**

**Peter Fischer**

Laboratory of Food Process Engineering, ETH Zurich, Zurich 8092, Switzerland

The non-monotonic shear flow of viscoelastic equimolar aqueous surfactant solution is investigated in a transparent Taylor-Couette flow cell. This particular wormlike micellar solution exhibits first a shear thinning and then a pronounced shear-thickening behavior. Once this shear-thickening regime is reached a phase separation of the solution into turbid and clear ring-like patterns are built up perpendicular to the neutral flow direction of a Taylor-Couette cell, i.e. stacked like pancakes. The solution exhibit several unique features as a) no induction of the shear induced phase, b) no structural build-up at the inner rotating cylinder, c) jumping pancake structure of clear and turbid ringlike phases, and d) oscillating shear stresses once the pancake structure is present. According to our analysis this flow phenomena is not purely a mechanical or rheological driven hydrodynamic instability but one has to take structural changes of the oriented micellar aggregates (flow induced non-equilibrium phase transition) into account, as proposed by several other authors as well. Although this particular flow behavior and the underlying mixture of shear induced phases and mechanical instabilities is not fully understood yet some classification characteristics based on a recent theoretical approach by Schmitt et al. can be used to describe the coupling between the flow instability (non-homogeneous flow profile due to the bands) and the structural changes. In reference to the presented model the observed orientation of the rings is typical for complex fluids that undergo a spinodal phase separation coupled with a thermodynamically flow instability. In contrast to other shear banding phenomena this one is observed in parallel plate, cone-plate, and Couette flow cell as well as under controlled stress and controlled rate conditions. Therefore it adds an additional aspect into the present discussion on shear banding phenomena, i.e. the coupling of hydrodynamics and phase transition of rheological complex fluids.

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PO7

**VISCOSITY UPTURN IN DYNAMIC OSCILLATORY MEASUREMENTS**

**Kyu Hyun, Do H. Kim, Seung J. Park, Kyung H. Ahn, and Seung J. Lee**

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Shear thickening, the phenomenon in which the steady shear viscosity goes up as shear rate increases, is often observed in some polymer solutions. The type of shear thickening is quite diverse. Viscosity may go up, up and down, or down and up and down with shear rate depending on situations. This interesting behavior arises when the microstructure of the material changes with shear, and is basically nonlinear because it happens at high shear rate. This nonlinear behavior attracts much attention in these days. In some literatures, viscosity upturn in dynamic oscillatory measurement is also reported. Complex viscosity goes up as frequency increases in this case. Viscosity upturn can be observed in some stress control type rheometer when parallel plate fixture is used. It disappears, however, when the fixture is cone and plate or cone and cylinder. Rate control type rheometer does not show this kind of behavior. At present it looks like that it is an instrumental artifact. More discussion on this phenomenon will be presented.

Monday 5:30 Savannah Foyer North

PO8

**THE ORIENTATION PROCESS OF CHOLESTERIC LIQUID CRYSTALS WITH D-(+)-  
MANNOSE AS CHIRAL INDUCTOR**

**Edgard G. Fernandes Jr. and M. Regina Alcantara**

Institute of Chemistry, University of Sao Paulo, S. Paulo, S. Paulo 05508-900, Brazil

The rheological behavior of cholesteric lyomesophases can give information about the chiral forces involved on the formation of the cholesteric arrangement. In the present work, it was studied the effect of water availability on the orientation process of lyotropic liquid crystal systems submitted to flow. It was prepared different mesophases based

on decylammonium chloride with different amounts of D-(+)-Mannose added as inductor. For the rheological studies it was used a Brookfield cone-and-plate rheometer, model LV-DVIII. The samples were sheared on a constant shear rate (100 1/s) with measures taken on each 30 s until 500 points is reached. The temperature was maintained at 25.0 °C and the measures were made under both water-saturated atmosphere and room humidity atmosphere. The water activity was measured using the equipment Aqualab (Decagon Devices, Inc.) before and after the samples were sheared. The obtained results showed that the flow orientation process on cholesteric lyomesophases should involve a breakdown of the helical structure originating fragments of helix, followed by their rearrange to form a new helical structure in the direction of the flow. Finally it was possible to observe the accommodation of the micelles on a new structure seeking the best orientation of the system on the flow direction. In general, it can be observed that the flow orientation process should be largely influenced by the amount of water present on the system. The obtained results showed that the content of water available could determine the existence of fragmentation, rearrange and accommodation stages. The water absorbed from the atmosphere during the shear process will help on the fragments hydration during the fragmentation stage. On the other hand, the water deficiency during this same stage can cause the suppression of this process. Finally it can be said that as larger the amount of water present in the system, faster will be the flow orientation process as a whole. (FAPESP)

Monday 5:30 Savannah Foyer North

PO9

**VECTOR CHROMATOGRAPHY: MODELING MICROPATTERNED SEPARATION DEVICES**

**Kevin D. Dorfman and Howard Brenner**

Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139

The theory of macrotransport processes (generalized Taylor dispersion theory) for spatially periodic media is invoked to model vector chromatographic separation and dispersion phenomena occurring in micropatterned separation devices, such as microlithographic arrays utilized for DNA electrophoresis. The generic theory rigorously extracts, from the local scale hydrodynamics and transport phenomena, the global scale hydrodynamic and transport properties of the solute to be separated, namely the effective chromatographic mobility and dispersivity dyadics. By way of illustrating the general notions in a simple physical context, results are presented for the specific case of a Brownian sphere translating under the influence of an external force through alternating layers of fluid, where the fluid layers possess differing viscosities and with which the solute does not necessarily form an ideal solution. The coarse grained mobility, and thereby the effective viscosity, is shown to be transversely isotropic with respect to the symmetry axis of the layers, thereby yielding multiple vector chromatographic scenarios wherein solutes are separated spatially, as well as temporally. Dispersion analysis reveals that convective forces invalidate the Nerst-Plank-Einstein equation on the macroscale, thus making it impossible to extract the dispersive characteristics of the separation solely from the essentially hydrodynamic information embodied in the effective viscosity.

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PO10

**SEDIMENTATION OF SYMMETRIC BODIES IN AN OLDROYD-B FLUID**

**Ashwin Vaidya<sup>1</sup>, Giovanni Galdi<sup>1</sup>, and Adelia Sequeira<sup>2</sup>**

<sup>1</sup>Mechanical Engineering, University of Pittsburgh, Pittsburgh, PA 15261; <sup>2</sup>Mathematics, Institute Superior Technic, Lisbon, Portugal

This study is motivated by the sedimentation experiments performed by Liu and Joseph (1993) regarding the orientation of elongated bodies in a viscoelastic fluid. It is well known that whereas elongated objects will sediment broadside on in a Newtonian fluid, they fall with their longer side on in a viscoelastic fluid. The observation of intermediate angles, which we shall call the tilt angle, in the above experiments has led to our current study. Although Joseph and Feng (1996) provide a qualitative explanation for this phenomenon, a rigorous mathematical explanation remains to be desired. It is claimed that the phenomenon of the tilt angle arises out of the competition of inertial versus viscoelastic torques on the sedimenting body. To test this hypothesis, we model the problem with an Oldroyd-B fluid. The only explicit computation for this problem was by Huang, Hu and Joseph (1998) who performed a 2-dimensional numerical simulation. In this work we perform a rigorous mathematical analysis and explicitly calculate the first order contribution of the inertial and viscoelastic torques acting on ellipsoids of different eccentricities in 3-dimensions. The analysis shows there is no tilt angle. Finally, our results are compared with the experiments of Liu and Joseph.

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PO11

**AN EXPERIMENTAL STUDY OF THE MIXING OF DOUGH****David M. Binding and Mark A. Couch**

Department of Mathematics, University of Wales Aberystwyth, Aberystwyth, Ceredigion SY23 3BZ, United Kingdom

This poster will illustrate the results of a programme of experimental work aimed at investigating industrial dough mixing processes. The findings of the experimental programme are used to aid the development and validation of numerical simulations carried out at UW Swansea. One of the principal aims is the development of tools that will permit the quantitative assessment of the efficiency of different designs, particularly of the mixer blades. Simple idealized dough mixtures are first characterized rheologically in terms of shear viscosity, dynamic moduli and extensional viscosity, in order to facilitate the development of model fluids i.e. translucent fluids with flow behaviour designed to mimic that of the dough. These model fluids are then used in flow visualization work carried out to determine the streamlines and velocity field associated with flows in fully filled model geometries, intended to simulate the mixing process in two dimensions. Two mixer geometries, one with one stirrer and the other with two, are studied at various speeds of rotation. Streamlines are obtained via the conventional laser scatter technique with 'still' photography while the velocity field is determined from data acquired with a digital high-speed camera and motion analysis procedure. The next phase of the work considers mixing where the geometries are partially filled. Clearly, 3-D transient flows with free surfaces are now involved. In addition, issues of 'wetting' and 'peeling' come into play. Experiments are undertaken to determine the stresses associated with the peeling of dough and model fluids from different surfaces. The peeling stresses are found to be strong functions of strain rate and compressive load. Visualization of the peeling is also facilitated via the digital high-speed camera. The resulting data is applied to the developing simulations to provide the appropriate conditions at the solid/liquid interfaces.

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PO12

**PREPARING CONSTANT VISCOSITY SOLUTIONS BY BLENDING GELATINS OF DIFFERENT MOLECULAR WEIGHTS****Richard W. Connelly**

Analytical Technology Div., Eastman Kodak Research Labs., Rochester, NY 14650-2109

This work is part of a program to investigate the effect on the physical properties of gelatin of varying the molecular weight distribution. The approach used was to make a series of solutions, at constant gelatin concentration (10%), from gelatins covering a wide range of molecular weights. This resulted in a series of samples with viscosities from 4cP to 60cP. Binary blends were to be prepared by mixing samples from the group below 10cP with ones from the group with viscosities above 10cP. At some ratio of these components one should be able to make a final solution of 10cP. The challenge was to determine the ratio of the two components that resulted in the 10cP mixture.

We will show the results of three separate blending schemes. The first was referred to as "linear blending"; for example using equal amounts of a 5cP and a 15cP sample, which didn't work. The second approach was a classic approach based on first principals and some knowledge of the individual molecular weight distributions. This approach worked better but did not have sufficient precision. The third approach was to develop an empirical blending model based on all the trial mixtures that had been prepared in testing the first two approaches which was very successful.

Monday 5:30 Savannah Foyer North

PO13

**RHEOLOGY OF WHEY PROTEIN ISOLATE/PECTIN MIXED GELS****M Beaulieu and Sylvie Turgeon**

Département des sciences des aliments et de nutrition, Université Laval, Québec, Canada, Québec G1K 7P4, Canada

Gelation and phase separation in food biopolymer mixtures are active research areas and previous studies have shown the great potential of these blends for the improvement of food texture and the development of new products. Many factors can affect the structure and the rheological properties of mixed gels as ratio of biopolymers, pH, mineral content, etc. Gelation of single and mixed solutions of whey protein isolate and pectin at different pH and with calcium or sodium was investigated using small-deformation dynamic rheometry and a series of experimental

sweeps of time-temperature, frequency, and strain. Gel microstructure was observed using confocal laser scanning microscopy. The type and proportion of pectin, as well as the calcium or sodium concentration affected elastic moduli of gels. White gels were observed indicating aggregation of whey proteins. Confocal microscopy revealed a ball pattern protein gelation at certain pH and salt concentration. Biopolymer concentrations, salt, pH and thermal history can be used to freeze the structure during the phase separation process and probably modify rheological and textural properties of the resulting gels.

Monday 5:30 Savannah Foyer North PO14

**THE RELATIONSHIP BETWEEN RHEOLOGY, APPLICATION METHOD, AND FINAL COATING STRUCTURE**

**Basant G. Dimetry and Douglas Bousfield**

Dept. of Chemical Engineering, University of Maine, Orono, ME 04469-5737

Suspensions of with polystyrene plastic pigments, kaolin, and CaCO<sub>3</sub> particles are made with different molecular weights of carboxymethylcellulose (CMC). The suspensions are characterized for their steady shear viscosity and viscoelastic properties. In addition, the increase in their storage modulus is measured as a function of time after a given shear history. These suspensions are coated onto plastic films and their final properties are evaluated. The increase in the storage modulus is not a function of molecular weight of the CMC, but it does depend slightly on the particle size. Some suspensions showed the opposite behavior, but this was from the settling of the particles in the rheometer. The increase in the storage modulus and the decrease in the phase angle shows an increase in the structure of the suspension. Suspensions with high storage moduli result in coating layers that are low in gloss and high in void fraction.

Monday 5:30 Savannah Foyer North PO15

**DMA PROPERTIES OF SHEET MOLDING COMPOUNDS (SMC)**

**Fariborz Parsi<sup>1</sup>, Bryan Clark<sup>1</sup>, and Stephen Gullerud<sup>2</sup>**

<sup>1</sup>Composite Materials Engineering, Winona State University, Winona, MN; <sup>2</sup>Watlow Polymer Technologies, Winona, MN

Dynamic Mechanical Analysis (DMA) has become a common tool in analytical laboratories. In this study, DMA was used to monitor and measure the rheological properties of sheet molding compounds (SMC) after delivery to the manufacturing site, and during the molding process. Sheet molding compounds are extensively used in transportation, construction, appliances, and many other applications. Due to their complex material nature and manufacturing conditions, it is of prime importance that the rheological properties of these materials be measured and understood. In this work, we present the results of our measurements using two commercially available equipment (Rheometrics RDS and Alpha Technologies APA 2000).

Monday 5:30 Savannah Foyer North PO16

**THIXOTROPIC PROPERTIES OF AQUEOUS DISPERSIONS OF POSITIVELY CHARGED AL/MG MIXED METAL HYDROXIDES**

**Dejun Sun, Wanguo Hou, and Chunguang Zhang**

Key Lab of Colloid and Interface Chemistry, Shandong University, Jinan, Shandong 250100, China

The rheological properties of aqueous dispersions of the Al-Mg mixed metal hydroxide (MMH) have been investigated. Special emphasis has been laid on the phenomenon of thixotropy. Structural recovery at rest after steady shear is considered a fundamental thixotropic process and has been characterized by steady shear and small amplitude oscillatory shear measurements. With increasing MMH concentration, the behavior changes from predominately viscous to a solid-like response. The magnitude of the storage modulus increases strongly and becomes less dependent on frequency with increasing MMH concentration. After cessation of steady shear complex viscosity increases monotonically with time and even after 3 hours no equilibrium viscosity value is reached, while shear stress under low shear rate approach equilibrium only after about 10 minutes. The recovery of MMH suspension after cessation of steady shear is strongly affected by pre-shear history and rebuilding time. The greater the intensity of preshearing, the lower the values of the elastic moduli after preshearing has ceased; the longer the

rebuilding time, the larger the values of the elastic moduli. These results are similar to those obtained for clay dispersions of different ionic strength and clay concentration. Considering the similarities in particle size and shape, the similar phenomenally macroscopic rheological properties between the two particulate systems provide indirect evidence of similar rebuilding mechanism for suspension structure. For MMH suspension, it is the long range of double layer repulsion between the positively charged MMH particles, that lead to the formation of solid-like structures; in contrast, for laponite suspensions, it is the repulsive forces between negatively charged particles that cause the formation of gel-like structures.

Monday 5:30 Savannah Foyer North PO17  
**YIELD STRESS MEASUREMENT OF SILICON NITRIDE MIXTURE SUSPENSIONS**  
Lixuan Zhu, Daniel De Kee, and Kyriakos Papadopoulos  
 Department of Chemical Engineering, Tulane University, New Orleans, LA 70118

Static yield stress values of aqueous ceramic suspensions were directly measured using a novel slotted-plate device, which substantially eliminated wall effects associated with an earlier version of the instrument. The ceramic powders were mixtures of silicon nitride, yttria and alumina. The relation between the suspension yield stress, solids concentration, pH, component ratio and temperature was investigated. A numerical finite element analysis method was used to compute the yield stress, stress and strain of bulk suspensions in the vicinity of the plate during yield procedure. Results were compared with the experimental data.

Monday 5:30 Savannah Foyer North PO18  
**PROPERTIES OF THE FORPOLYMER OF N-VINYL PYRROLIDINE WITH ITACONIC ACID, ACRYLAMIDE AND 2-ACRYLAMIDO-2-METHYL-PROPANESULFONIC ACID AS FLUID LOSS REDUCER FOR DRILLING FLUID AT HIGH TEMPERATURE**  
Yumin Wu, Dejun Sun, Baoqing Zhang, and Chunguang Zhang  
 Key Lab of Colloid and Interface Chemistry, Shandong University, Jinan, Shandong 250100, China

The forpolymer of N-vinyl pyrrolidone (NVP), itaconic acid (IA), acrylamide (AM) and 2-acrylamido-2-methyl-1-propane sulfonic acid (AMPS) is synthesized through the free-radical polymerization, and characterized using FTIR. The colloidal properties of the drilling fluid are investigated in the form of fresh-water or salt-water mud. It is found that the NVP-IA-AM-AMPS forpolymer has strong effects on mud properties. The filtrate volume decreases with the increase of the forpolymer concentration before or after aging test at 220°C, and the filtrate volume after aging test is larger than that before aging test; but still very small compared with the corresponding base mud (without the forpolymer). In addition, the rheology properties (the apparent viscosity, the plastic viscosity and the yield point) of both fresh-water mud and salt-water mud are modified by the forpolymer. The particle size data demonstrates that the average size of the clay particle after aging test is larger than that before aging test, and the particle size distribution after aging test is wider. Therefore, the drilling fluid containing the forpolymer has an excellent tolerance to salt and high temperature, and the forpolymer behaves an efficient drilling fluid reducer at the high temperature of 220°C.

Monday 5:30 Savannah Foyer North PO19  
**RHEOLOGICAL AND TRANSPORT PROPERTIES OF SUSPENSIONS**  
Allen E. Kaiser and Alan L. Graham  
 Chemical Engineering, Texas Tech University, Lubbock, TX 79409

Rheological and transport properties of suspensions of neutrally buoyant, non-colloidal spheres were investigated with the specific aim of determining the nature and extent of wall-effects. Falling ball rheometry was used to determine the reduced viscosity of suspensions of hard spheres in Newtonian suspending media. In one set of experiments, the distance from the center of the sphere from the center of a containing cylinder ( $b$ ) was varied; in this experiment, it was found that dilute and moderately concentrated suspensions exhibit essentially Newtonian wall effects while highly concentrated suspensions exhibit wholly different behavior. Off-center falling ball experiments were performed in suspensions with small  $R/a$ s ratios; in this case, the inward migration of the falling ball dropped near the cylinder wall is used to determine the local micro-structure and packing of these suspensions. These results are coupled with nuclear magnetic resonance imaging (MRI) data and used in the determination of

wall effects in concentrated suspensions. These results indicate that the strong micro-structural layering near the cylinder walls greatly influences the velocity of the falling ball and will impact any viscosity determination using this as its basis. In the final experiment, small clusters of neutrally buoyant spheres were placed near the inner and outer walls of Couettes. The inner rod was then turned at a constant rate and the migration of the spheres was then measured over time. It was found that clusters of spheres at both the inner and outer walls of the Couette migrated towards the annular space of the device; however, the clusters placed near the inner, moving rod migrated at a much faster rate and a greater overall distance than did the clusters initially placed at the outer wall. In all experiments, it was found that the walls containing a suspension play a large factor in the rheological and transport properties of suspensions.

Monday 5:30 Savannah Foyer North

PO20

**ON THE EFFECT OF COMPATIBILIZATION ON INTERFACIAL SLIP IN POLYMER BLENDS**

**Peter Van Puyvelde<sup>1</sup>, Zachariah Oommen<sup>1</sup>, Gabriel Groeninckx<sup>2</sup>, Paula Moldenaers<sup>1</sup>, and Jan Mewis<sup>1</sup>**

<sup>1</sup>Department of Chemical Engineering, Katholieke Universiteit Leuven, Leuven 3001, Belgium;

<sup>2</sup>Department of Chemistry, K.U. Leuven, Leuven 3001, Belgium

The viscosity of an uncompatibilized polymer blend often shows a negative deviation from a log-additivity rule at shear rates relevant to processing conditions. This deviation has been attributed to interfacial slip. In this work interfacial slip and the effect of reactive compatibilization on this phenomenon is studied in blends containing ethylene-propylene rubber and nylon-6. In a first step, the viscosity and morphology of blends containing various amounts of nylon and compatibilizer is presented. Next the effect of reactive compatibilization on the rheology of multilayer structures is studied. In both cases it is demonstrated that reactive compatibilization suppresses interfacial slippage.

Monday 5:30 Savannah Foyer North

PO21

**PREPARATION OF RUBBER TOUGHENED SYNDIOTACTIC POLYSTYRENE BLENDS BY REACTIVE COMPATIBILIZATION**

**Won-mook Choi<sup>1</sup> and O Ok Park<sup>2</sup>**

<sup>1</sup>Chemical Eng., KAIST, Taejon 305-701, Republic of Korea; <sup>2</sup>Korea Advanced Institute of Science and Technology, Taejon, Republic of Korea

This study is about compatibilization of syndiotactic polystyrene(sPS)/ethylene-propylene copolymer(EPR) to increase impact strength of sPS by reactive blends. In order to prepare modified EPR, maleic anhydride(MA) is grafted on EPR by melt process and the formation MA-EPR is examined by FT-IR and elementary analysis. Oxazoline containing polystyrene(PRS) is chosen as third component because it is known that oxazoline group has good reactivity with MA group. The reaction between RPS and EPR-MA was examined by the FT-IR. The miscibility of sPS/RPS was characterized by thermal and rheological measurement. Along the various compositions, sPS/RPS blends showed single enthalpy relaxation peak and homogeneous rheological behaviors, which indicating that RPS is miscible with sPS. As varyin the ratio of RPS reactive agent to sPS/PER-MA blends, reactive compatibilization effect was characterized by thermal, impact strength, morphology and rheological method. As increasing the ratio of RPS, the impact strength of blends increase significantly; at 10phr RPS, 6 times of sPS impact strength, and small domain size and highly deformed domain by impact force were found. And in the rheological properties, storage modulus ( $G'$ ) increased and showed plateau region at low frequency, and complex viscosity ( $\text{Eta}$ ) increased significantly as the ratio of RPS.



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