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Rheology Bulletin

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Inside:

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On the Cover: Image courtesy of Bavand Keshavarz, Michela Geri, and Gareth McKinley (Massachusetts Institute of Technology). This snapshot was taken from the SoR 90th Annual Meeting, Gallery of Rheology Contest. The image depicts two viscoelastic fluid jets colliding in midair, giving rise to elongated jets and formation of beads-on-a-string phenomenon. Capturing such fast dynamics is not easy. Inspired by the work of Harold E. Edgerton, who pioneered the use of stroboscopic photography (e.g., his famous Milk Drop Coronet, 1957), the authors used a photographic light source known as an air-gap flash produced by a high-voltage discharge between two electrodes. By synchronizing the resulting flash to a detector (i.e., camera), this technique allows for high-speed imaging (usually in the nanosecond range), revealing phenomena that would be otherwise too fast for the naked eye.

The *Rheology Bulletin* is the news and information publication of The Society of Rheology (SOR) and is published yearly in July (in non-pandemic years). Subscription is free with membership in The Society of Rheology. Letters to the editor may be sent to Paulo E. Arratia at *parratia@seas.upenn.edu*

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Dear SOR friends and colleagues:

The past 18 or so months have been rough. The COVID pandemic has affected us all, some with only mild disruptions to daily life, but others with grief at the tragic and untimely loss of loved ones, or dramatic effects on their own health. I want to start off this letter with a note of gratitude to everyone who has made sacrifices large and small to help keep others safe during this difficult time.

I am also grateful to my fellow SOR committee members and volunteers, who have kept the Society moving forward these past months. The most visible aspect of this work is in our annual meetings. Of course, we were not able to meet in Austin in February. Fortunately, we were able to have a plenary awards session and Bingham and Metzner lectures at the 2020 International Congress on Rheology. My thanks to Anne Grillet, Andy Kraynik, Roger Bonnecaze, Marie-Claude Heuzey, Gerry Fuller and the ICR organizers, Paulo de Souza Mendes, Monica Naccache, and Ricardo Andrade, for making all this happen. I know I speak for many of us when I congratulate Paulo, Monica, and Ricardo for putting on one of the most successful virtual meetings of the COVID era. I'm also grateful to Roger for successfully negotiating to have the Austin meeting rescheduled to 2024.

And of course, there's the Bangor meeting in October! In a recent survey, SOR members indicated a strong desire for an in-person meeting as well as for a requirement that all attendees be fully vaccinated. We are in the process of implementing this requirement. We know that, unfortunately, many members of our community will not be able to join us in Bangor; my thanks go to the local arrangements coordinator, Albert Co, and the Technical Program Chairs, Cari Dutcher and Patrick Underhill, for the extra efforts they are undertaking to make enhancements to the live meeting that will enable some remote participation. We will be providing more details as plans become firmer.

We have seen many changes in the Society in the past year. This issue of the Rheology Bulletin marks the debut of our new Bulletin Editor and communications coordinator Paulo Arratia! Paulo will be guiding the future, not just of the Rheology Bulletin, but also of SOR communications more broadly. Another change is the Society membership's overwhelming vote to approve a standing Diversity, Equity, and Inclusion committee. Thanks very much to Norm Wagner and Kelly Schultz for getting this important initiative off the ground. The more generously we welcome all who wish to contribute to the SOR community, the more our community will flourish.

The last change I want to mention lies at the heart of our Society's mission: publication of the Journal of Rheology. Ralph Colby has led the journal for a decade. In that time frame, the journal has continued to thrive, despite the increasingly competitive publishing landscape. Submissions to JoR have steadily increased -- 2020 was a record year for submissions, with 227, almost twice as many as in 2011! This is one reason that Roseanna Zia was brought on board as Associate Editor. Average time from submission to acceptance has decreased by almost 50% from 2016, and the journal's impact factor is the highest of any rheology-focused journal (3.7 in 2019), with further increase projected for 2020. With all these successes, Ralph has decided that a decade at the helm is enough and will be ending his term as Editor at the end of this year. On behalf of the entire Society, I want express my gratitude to Ralph for his dedicated leadership and service. We are in the process of choosing his successor. **And of course, please remember that publishing your best work in the Journal of Rheology directly supports the Society**!

Take care, everyone. I hope to see you in Bangor.

Mike Graham
President, The Society of Rheology

International Congress of Rheology (ICR) 2020 - Rio de Janeiro, Brazil

By Paulo R. de Souza Mendes & Monica Naccache (PUC - Rio de Janeiro)

The Organizing Committee of the International Congress of Rheology (ICR) 2020 would like to thank the international rheology community for choosing us to care for the most important congress of our community; ICR dates to 1948. The process of organizing this meeting began many years ago. We were encouraged by many of you, our fellow rheologists who we met at conferences around the world and who visited the Rheology Group in Rio de Janeiro (Brazil).

We started getting involved with the ICR organization nearly six years ago. In the early stages, we created the Scientific Advisory Committee. Then, with the help of the Advisory Committee, we defined the symposium themes. Next, we invited Symposium Organizers, three organizers for each of the twelve symposia. As you can imagine, there were many of us involved in this effort. The active participation of all these people was essential for the organization, and we thank them all very much for their collaboration.

Just like any other human activities, ICR 2020 organization was severely impacted by the COVID pandemic. We had contracts with a lovely hotel by the beach, with a place for a good Brazilian barbecue party, but these and other activities had to be cancelled. Most of our plans, which we painstakingly put together, had to be abandoned last August when the reality of the pandemic forced us to go virtual. The challenge now was to organize a virtual ICR, with no previous experience or successful models to follow and little time. These were challenging times, but with hard work and help from the community, we believe that we were able to provide a relatively good experience despite a few issues related to internet connectivity. Overall, ICR Rio was a virtual success!

We thank our sponsors, especially TA, Anton Paar and FAPERJ, for the participation and financial support. The support and encouragement of The Society of Rheology throughout the years was also essential. Special thanks are due to Albert Co, who made available his excellent technical program administrator system, and gave us support on how to use it. We hope to see you in Rio, this time for real, sometime soon.

A few snapshots from the virtual ICR meeting in Rio de Janeiro.

Paulo and Monica share a well deserved celebratory drink to commemorate a successful meeting.

The 92nd SoR Annual Meeting

By Cari Dutcher & Patrick Underhill

Fall is upon us and we are busy preparing for the 92nd Annual Meeting of The Society of Rheology to be held in Bangor, Maine on October 10-14, 2021; with both the Short Course (more below) and Rheology Research Symposium (RRS), bringing together students and professionals to explore career development in the field of rheology, occurring on October 9th and 10th. The technical meeting, short course, and RRS will all take place at the Cross Insurance Center, a facility with more than 25,000 square feet of flexible, indoor meeting space. The local arrangements chair is Albert Co, and we thank Albert for all of his hard work to create a warm welcome for us.

Bangor is the third-largest city in the state of Maine. It serves as the retail, cultural, and service center for central, eastern, and northern Maine, as well as Atlantic Canada. About 50 miles from Bangor is Mount Desert Island, home of Bar Harbor and the Acadia National Park, one of the top 10 most-visited national parks in the United States. Further away at about 75 miles from Bangor is Baxter State Park, where one can find Mount Katahdin, Maine's highest mountain peaks at nearly a mile (5,267 feet) high and the most northern point of the Appalachian Trail. The average high and low temperatures in Bangor during October are 59°F and 38°F, respectively, with an average precipitation of 3 inches.

Mount Katahdin in Baxter State Park. Image by David Mark from Pixabay.

This year, the two-day Short Course will be on "Colloidal Gels: Formation, Structure, and Rheology". The stellar team of instructors includes Matthew Helgeson at UC Santa Barbara, Roseanna Zia at Stanford University, and Safa Jamali at Northeastern University. In addition to in-person participations of the short course, we are also offering an online option with live streaming of the real-time lectures synchronously. The Society of Rheology is also offering a limited number of free student registrations for the short through the International Outreach Program, to support students of rheology at international institutions who are members of The Society of Rheology or their local rheology society. The student could attend the short course in-person or online.

Cross Insurance Center with Paul Bunyan Statue, Venue of Technical Program, Short Course, and Rheology Research Symposium. Image by Justin Russell Photography. Courtesy of Greater Bangor Convention and Visitors Bureau.

Cari Dutcher and Patrick Underhill, the meeting's technical co-chairs, have put together a terrific program for the 92nd meeting. The Annual Meeting will have ten thematic sessions, a poster session (which includes the annual Student/Post-doc Poster Competition), and the Gallery of Rheology Contest. The plenary lectures will be given by Petia Vlahovska (Engineering Sciences and Applied Mathematics, Northwestern University), Michael Solomon (Chemical Engineering, University of Michigan) and the 2021 Bingham Medalist, Jan Vermant (Department of Materials, ETH Zürich). A presentation will also be given by the 2021 Metzner Awardee, Quan Chen (Changchun Institute of Applied Chemistry, Chinese Academy of Sciences). Finally, for those members with travel limitations, a limited virtual experience is also being offered. The virtual events include live streaming of the plenary sessions, live streaming of the Society business meeting, live Thursday morning networking session, and participation in the Gallery of Rheology Contest and the Pre-recorded Flash Presentations virtual session.

We hope to see you in Bangor this October!

92nd SoR Annual Meeting Plenary Lecturers

Prof. Petia Vlahovska
Northwestern University
Engineering Sciences and Applied Mathematics
Soft interfaces and active matter

Prof. Michael Solomon
University of Michigan
Chemical Engineering
Colloidal self-assembly and gelation

Technical Program

- **Technical Program Chairs: Cari Dutcher (Minnesota), Patrick Underhill (RPI)**
- **Plenary Lectures: Petia Vlahovska (Northwestern), Michael Solomon (Michigan)**
- **Bingham & Metzner Lectures**
- **Poster Session Chairs: Gwynn Elfring (UBC), Jeff Richard (Northwestern)**
- **10 Technical Program Areas:**

1. Suspensions, Colloids, and Granular Materials (Heuzey, Hashmi, Pandey)
2. Active and Biological Materials (Datta, Mai)
3. Polymers Solutions, Melts, and Blends (Vlassopoulos, Evans, Padmanabhan)
4. Applied Rheology and Rheology Methods (Ansari, Mckenzie, Läuger)
5. Additive Manufacturing and Composites (Cai, Park)
6. Rheology and Mobility at Interfaces (Anderson, Narsimhan)
7. Foams, Emulsions, Surfactants, and Micelles (Cardinaels, Salonen, Velankar)
8. Arrested Systems: Gels and Glasses (del Gado, Seth)
9. Micro- and Nanofluidics and Confined Flows (Yin, Marciel)
10. Flow-induced Instabilities and Non-Newtonian Fluids (Grecov, Bischofberger, Perazzo)

Diversity & Inclusion Efforts

By Kelly Schultz

The Society of Rheology Diversity, Equity and Inclusion (DEI) Committee has been working to set policies around DEI within the society, develop programs that will enhance DEI and actively diversify the membership of the society. SOR has officially adopted a DEI statement on June 21, 2020 crafted by members of this Committee and the Executive Committee. This statement reads:

The mission of The Society of Rheology is to expand the knowledge and practice of rheology through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what rheology is, and how it impacts humanity and the world. To achieve this mission, The Society of Rheology is committed to promoting diversity, equity and inclusion among all of our members, as well as more broadly throughout the field of rheological sciences and practice of rheology. Through our actions, we strive to value and respect all individuals, regardless of race, religion, national origin, sexual orientation, ethnicity, gender and gender identity, physical appearance and ability, socioeconomic background, region, and immigrant, military, or veteran status. This value and respect is also not contingent on discipline, employment sector or educational status. The Society of Rheology also seeks to understand and remove barriers to diversity, equity and inclusion in our community, as well as obstacles to professional growth and advancement of our membership.

In addition to crafting this statement the DEI Committee has been active. We have become a standing committee, which was voted on and overwhelmingly supported by the membership of SOR. We have also begun preparations for the 2nd Annual Rheology Research Symposium (RRS) that will be held prior to the 92nd Annual Meeting in Bangor, ME, October 9-10, 2021. The 1st Annual RRS was held in Raleigh, NC and was a great success. A goal of the RRS is to build a mentoring community within SOR by creating a multi-tiered mentoring structure that includes young and established rheologists. These mentoring groups give young rheologists the opportunity to learn about our community and also integrates them into the fabric of SOR. It will give established rheologists the opportunity to interface with the future of rheology. The program this year will also focus on DEI issues in STEM.

In the near future, we will be putting out a call for applications to graduate students and recruiting mentors, speakers and panelists for the RRS. To get involved with the next RRS, please contact any member of the DEI committee. The members of the SOR DEI committee are Jennifer Hofmann (Stanford U, graduate student member), Lilian Hsiao (North Carolina State U), Safa Jamali (Northeastern U), Ali Mohraz (UC Irvine), Susan Muller (UC Berkeley), Kelly Schultz, chair (Lehigh U), Maryam Sepehr (Chevron), and Norman Wagner (U Delaware). For further information on the RRS please visit our website at web.northeastern.edu/sordiversity/. The RRS is supported by an American Institute of Physics (AIP) Venture Partnership Fund grant.

Participants of the 1st Annual Rheology Research Symposium in Raleigh, NC.

Special Issue on Double Dynamics Polymeric Networks

Guest Editors: Evelyne van Ruymbeke and Tetsuharu Narita

Expressions of intent to submit a paper are invited for a special issue of the *Journal of Rheology*. Scheduled for publication in June 2022, this issue will focus on the properties of polymeric networks exhibiting double or multiple dynamics, such as dual networks or interpenetrated polymer networks, with particular emphasis on systems which combine supramolecular reversible junctions of different nature, or combine reversible junctions, entanglements and/or chemical crosslinks. Submissions are welcome from the entire spectrum (experiments, simulations and theory).

This special issue marks the final meeting of the European *Initial Training Network* DoDyNet. The peer-reviewed articles from this special issue may be presented by invitation in a focused discussion workshop which will be held in Crete in late May, 2022 (for more details and registration, see https://www.dodynet.eu/). Accepted articles will be circulated among authors participating in the special issue or the workshop, for comments and questions that will be published along with replies from the authors.

Expression of Intent

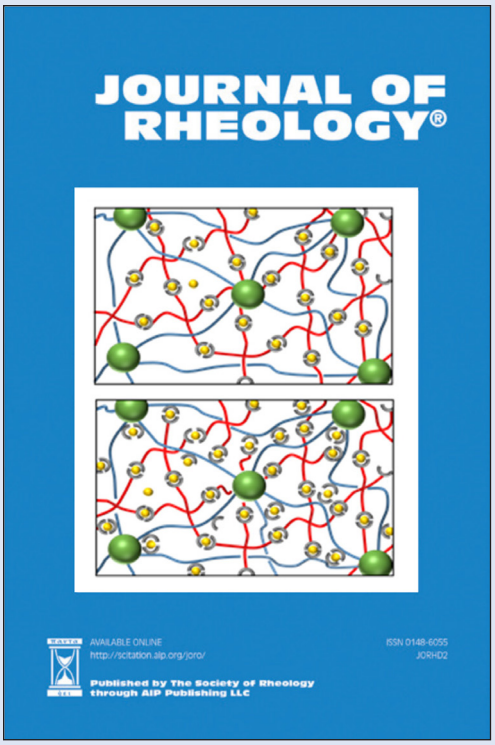
If you plan to submit a paper, expressions of intent are encouraged at your earliest opportunity, as it would be useful for us to have a list of potential contributors prior the submission deadline.

- Please inform us by e-mail to

  JOR-EditorialOffice@aip.org

- Use **INTENT - Special Issue/Double Dynamics Networks** in the subject header of your message.
- Indicate a tentative title for your manuscript.
- Include contact author's name, institution and email, and those of known or proposed co-authors.

DEADLINE FOR SUBMISSIONS: **November 1, 2021**



Ole Hassager 2020 Bingham Medalist

—Nicolas J. Alvarez

It is a great honor and pleasure to introduce the 2020 Bingham Medal recipient, Professor Ole Hassager. I was fortunate to study under Ole's mentorship for three years and am forever grateful for his friendship and guidance. What follows is a short biography of Ole's life and scientific achievements.

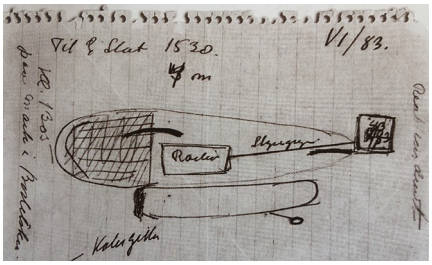


FIGURE 1. Sketches made by Hassager Christiansen. Reproduced from Knudsen (2000).

Early Years: Ole was born on the small island of Bornholm (588 km^2) in the Baltic Sea. While this may not seem especially notable given that Denmark (42,933 km^2 excluding Greenland) is composed of 443 named islands and one peninsula, Bornholm is quite special in its location and isolation. For one, it is closer to Sweden than it is to Denmark. The island is located off the southeast coast of Sweden, and is approximately 250 km by boat from Copenhagen, Denmark's largest city. The island sits advantageously in the center of the Baltic Sea and is a strategic stronghold between Germany and Sweden. For this reason, the German's captured and occupied the island in 1940 and used it as a lookout post and listening station. It was during this occupation in 1943 that Johannes Hansen and explosive expert Lieutenant Captain Hassager Christiansen, Ole's father and source of his last name, made the brave decision to secretly photograph, sketch, and detail the yellow rocket that accidentally crash-landed into a turnip field on Bornholm. Although the German's confiscated copies of the photographs, their photos and sketches reached their intended target, the British intelligence service. These photos were the first sign of Germany's aspirations to develop flying bombs and rockets, which were later to become known as V-1 and V-2. It was later reported that the skillful and accurate reports, drawings, and photographs helped the British correctly conclude the means of propulsion, the rocket principle, and the remote control (Kure, 1981). Several years later, Ole was born and gifted with his father's attention to detail and scientific interest. This is evident from his gymnasium (high school) report card from 1964-65 showing excellent marks in science and mathematics. It also clearly shows Ole's

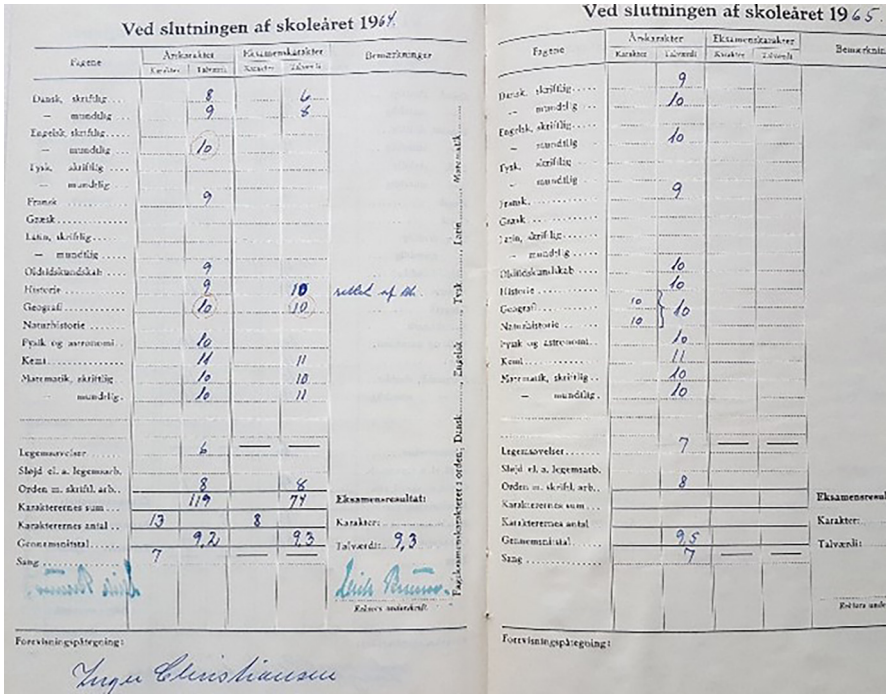


FIGURE 2. Report card from high-school showing excellent marks in math and science, but poor marks in singing and sports.

FIGURE 3. A photo of Ole trying to blend in during his college years.

disinterest for sports "legemsøvelser" and music "sang". Fortunately, singing did not count in his GPA "gennemsnit", unfortunately sports did!

After gymnasium on Bornholm, Ole moved to Copenhagen to pursue a degree in Kemiteknik (Chemical Engineering) at the Technical University of Denmark (DTU). After graduating with his master's degree, he made the unpopular and difficult decision to continue his graduate education in the United States. At that time (late 1960s), Denmark was experiencing a wave of anti-American sentiments arising from intervention in Indochina and the Vietnam War. Furthermore, the student revolution was well underway, and if you were not part of the movement, you were part of the problem. Ole recounted that he often studied in solitude and secret so as not to catch the attention of his fellow student revolutionaries. The picture to the left shows Ole blending in with his fellow students. It is unclear whether she is buying his sympathy to "the cause". After graduation with just a large Danish mailbag filled with his possessions, Ole set out to pursue his PhD at the University of Wisconsin, coincidentally a state that was settled by his Danish ancestors.

University of Wisconsin:

At the University of Wisconsin, Ole joined the group of Robert (Bob) Byron Bird where he began working on his thesis work concerning the kinetic theory of bead-rod models. Ole has very fond memories of his time in Wisconsin. Surprisingly, it was here and not on his home island that Ole discovered his passion for sailing, especially the M-20 scow (see Fig. 5). To the right we see a photo of his membership card to the Hoofer Sailing Club. To this day, he still instructs young sailors at a sailing club in the northern part of Copenhagen. After graduation, Ole was not quite ready to go back to Denmark. He decided instead with fellow research group member and office mate, Robert (Bob) C. Armstrong, to convince their advisor Bob Bird to co-author a textbook on the continuum theory of polymer flow. At that time, there was no textbook that covered both the continuum and molecular aspects of polymeric liquids. While Bob Bird tried to dissuade their efforts by detailing the incredible amount of work such an undertaking would require, the two were determined. Their efforts resulted in the landmark two-volume series entitled *Dynamics of Polymeric Liquids*, with a fourth author Charles F. Curtiss participating in Volume 2. Included below is a photograph of the three authors arranged in increasing height. After this herculean effort, Ole returned to Denmark to serve his mandatory military service in the Navy. You can see a photo of Ole in uniform. It is interesting to note that the blond gentleman clearly demonstrates that the Danish Navy was much laxer when it came to hairstyles than its US counterpart. After his military service (1976), Ole returned to take a faculty position at DTU, where he worked until his retirement in 2019. We now highlight some of Ole's scientific achievements during this time.

Scientific Achievements:

Ole Hassager's research has been devoted to the area of rheology and fluid mechanics of complex fluids. His early work was in the kinetic theory of polymer dynamics and in the analysis of non-linear constitutive equations for viscoelastic fluids. His initial work as a professor at DTU was centered on pioneering finite element simulation of Newtonian and viscoelastic flows via the Lagrangian kinematic specification. In 2000 he founded the Danish Polymer Center at DTU, an environment for both polymer chemistry and physics. It was during this time that Hassager transitioned from theoretician to experimental rheologist with special focus on non-linear extensional rheometry. He has published extensively, more than 140 publications, and his work has been extremely impactful to the rheological community

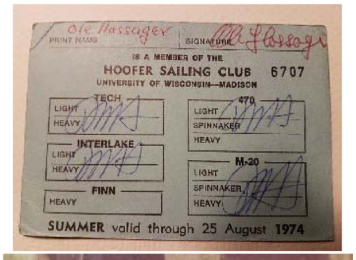


FIGURE 4. (LEFT) Ole in Danish navy uniform just after completing Dynamics of Polymeric Liquids and returning to Denmark. (TOP) A copy of Ole's Hoofer Sailing Club membership card. (BOTTOM) Left to right: Robert C. Armstrong, Robert Byron Bird, Ole Hassager.

FIGURE 5. A photo of Ole punting (with the intensity of steering an M-20 scow on the open sea) in Cambridge with Gareth McKinley (photographer & punt commander), and Shelley Anna (bottom right).

and beyond. Below we detail some more specific scientific achievements.

(1) ***Nonlinear extensional dynamics of entangled linear polymers:*** In 2003, Hassager and coworkers made the first measurements of steady extensional viscosity of a nearly monodisperse polymer melt. The purpose was to test the theoretical predictions of the Doi-Edwards (DE) constitutive equation for polymer melts. Until then, extensional experiments testing the DE model had been performed on room-temperature entangled polymer solutions. While polymer solutions showed a general agreement with the predictions of the DE model accounting for chain stretch, to the surprise of the rheological community polymer melt extensional measurements showed no such increase. This disagreement plagued the rheological community for nearly a decade. The first real breakthrough came when Hassager and co-workers managed to bridge solution and melt behavior using viscous oligomers as solvent. Only recently is a clear picture emerging that involves the nematic interaction between polymer chains in the melt state not possible in solution, and the increase of the distance between entanglements (and thus the segment extensibility) upon dilution. The Hassager group data is still the quintessential test for nonlinear constitutive models of polymer melts and blends.

(2) ***Nonlinear dynamics of industrial polymers:*** Long chain branched polyethylenes exhibit a remarkable overshoot in the tensile stress difference upon inception of constant rate extensional flow. These results have intrigued theorists and have been met with skepticism of experimental method. Hassager has played a leading role in the demonstration of the phenomenon and in putting it into a broader context in terms of comparison with cross-slot measurements, creep measurements, constitutive analysis and flow induced crystallization.

(3) ***Nonlinear extensional dynamics of model polymers of complex architecture:*** Hassager and co-workers have made significant contributions in the synthesis and rheological characterization of polymers of well-defined architecture as model systems to emulate industrial branched polymers. The stress overshoot was attributed to the presence of a "cross-bar" via the synthesis and rheology of a polystyrene 'Pom-Pom' molecule (or "H-polymer") with well-defined cross-bar. More recently Hassager and coworkers have confirmed the theoretical prediction by Ianniruberto and Marrucci that entangled melts of branched polystyrenes behave like linear polystyrenes in the steady state of fast extensional flow. Finally, in collaboration with last year's Bingham medalist (Dimitris Vlassopoulos) Hassager and coworkers discovered the unexpected dramatic strain hardening of entangled ring macromolecules.

(4) ***Finite element modeling of viscoelastic flow:*** Hassager has pioneered the application of the Lagrangian specification in both Newtonian and non-Newtonian fluid mechanics. This has led to finite element methods that handle 3D transient deformation and flow of non-linear viscoelastic materials with free surfaces with relative ease. For example, these efforts have been able to analyze and explain sample break-up in dual cylinder wind-up extensional measurements, such as the extensional viscosity fixture (EVF) and the SER device.

(5) ***Fracture in viscoelastic liquids:*** Hassager and co-workers were the first to combine extensional rheometry with high speed imaging in the investigation of fracture. The pioneering work is best summarized by a Viewpoint article by physics fracture expert Jay Fineberg who wrote: "Hassager and co-workers' study demonstrated that the classic fracture picture crosses over to a characteristic behavior first predicted by Pierre-Gilles de Gennes, in which the viscous response of the material dominates the elastic response….The idea of soft materials has challenged our classic notions of fluid and solid materials. Experiments such as these manifestly demonstrate that processes such as brittle fracture … can indeed take place in fluid-like materials…"

(6) ***Development of instrumentation for rheology:*** Hassager and co-workers pioneered the development of actively-controlled filament stretching rheometry with temperature control. For nearly a decade, Hassager's laboratory was the only place capable of performing filament stretching measurements on polymer melts. In 2015, a controlled filament stretching rheometer, the VADER1000, became commercially available from Rheo Filament ApS, a start-up company co-founded by Hassager. The EVF/SER fixtures and the VADER1000 rheometer are the only commercial instruments presently available for extensional melt rheology. Unique features of the VADER1000 are the ability to study tensile stress relaxation, tensile creep, and reversed flow in both polymer melts and solutions.

One recipe for Ole's success is his willingness and openness for collaboration. One such example is his third consecutive participation in a polymer-focused EU funded project. Many of these collaborations originate from discussions at meetings and invitations to spend time in Copenhagen as Ole's guest speaker. During my time at DTU, I was fortunate to enjoy several visits from researchers all over the world. It was a fantastic way of developing new ideas, talking about impactful problems, and developing a broader understanding of rheology and its role in industry and science. It is no wonder that Ole has always chosen thoughtful, impactful problems to solve. He certainly serves as a beacon for rheology in Northern Europe and continues to be an inspiration for young rheologists (me included). While his Danish modesty does not allow him to acknowledge his own significant achievements in science, join me in celebrating them for him. This year's Bingham medal goes to a most deserving rheologist, but more importantly to an amazing educator, advisor, and steward of science.

- (Knudsen 2000) Ann Vibeke Knudsen (ed), "Bornholm at War 1940-1946", Bornholm Museum (2000)
- (Kure 1981) Børge Kure, "An island at war, Bornholm's occupation history- based in the daily newspaper Bornholmeren" Rønne (1981)

Jan Vermant 2021 Bingham Medalist

—Gerald G. Fuller

I am honored to introduce the readers of the Bulletin to Jan Vermant, the winner of the 2021 Bingham Award of the Society of Rheology. I have known Jan since he was a graduate student and was his postdoc mentor. The two of us have collaborated over the years on problems related to interfacial rheology. I fondly recall one of my first meetings with Jan in 1994. He arrived at the Brussels' train station to collect me along with his wife, Karin, in a "European-appropriate-sized" car only to discover that my luggage included a mountain bike. Jan is a problem solver and quickly set things in motion to get me over to my hotel.

Jan is one of the finest rheologists worldwide and he is a leading figure in colloid and interfacial dynamics. His work includes important findings on dispersion rheology, and he is recognized for his innovative and foundational contributions to interfacial rheology. Indeed, he has profoundly influenced this latter topic through the development of new experimental methods, morphological control of model complex interfaces, and theoretical analysis of non-Newtonian

interfacial flows. His outstanding accomplishments were recognized by the leadership of the ETH and he moved to that institution to hold the first chair in soft materials. In 2019 Jan received the Weissenberg Award from the European Society of Rheology, one of the highest accolades of our profession.

What is most striking about Jan's research accomplishments is the combination of the *diversity* of physical phenomena and the *depth* of these investigations. Jan's experiments investigating the coupling of particle shape and capillarity to drive remarkable pattern formations by colloidal particles are a wonderful example of his ability to recognize key physical variables controlling physical phenomena in interfacial science. His 2011 paper in JACS is truly a *tour de force* on the discovery of new pathways to generate elaborate, chainlike structures.

Jan's work on bacterial swarming is an impressive application of interfacial flow physics and optical microscopy that led to the recognition of a mechanism of colony transport through Marangoni stresses. This work is beautifully captured in his 2011 Soft Matter paper on the subject, which is another example of Jan's ability to couple experiment with theory.

Understanding and controlling the composition and dynamics of emulsions are formidable challenges in the field of liquid-liquid interfaces, with profound technological implications. Jan has contributed significantly to the field and a jewel of the crown is undoubtedly where he been demonstrated, for the first time, that it is possible to control both surface coverage and composition of droplet interfaces at will (Nature Comm. 2018)).

Jan has made lasting contributions to instrument design in interfacial rheology. Most notable is the development of the "double-wall ring" interfacial shear rheometer, which allows one to convert conventional rotational rheometers into highly sensitive devices for the measurement of surface rheometric material functions. This device, which is now commercially available, has been adopted by numerous laboratories world-wide to address problems in emulsion, foam, and solution stability.

While a graduate student under the mentorship of Jan Mewis of KU Leuven, a part of Jan's thesis concerned superposition rheometry, where steady shear and oscillatory shear are combined. The tools available at that time made this application difficult. Jan is not one to let problems go unfinished and, recently, he has taken advantage of the flexibility of modern rheometers to demonstrate the striking ability of superposition rheometry to judiciously reveal flow-microstructure couplings (Phys. Rev. Lett. 2015).

Through targeted collaborations, Jan and his collaborators are also responsible for some of the finest measurements of interaction forces existing between particles trapped at oil/water interfaces. These forces are fundamental to understanding mechanisms of particle stabilization in Pickering emulsions and have been the source of debate for over a decade. This body of work is an important demonstration of Jan's authoritative grasp of colloidal physics and judicious experiments coming from his collaboration with Eric Furst's group. Another example is his collaboration with John Brady to experimentally test the concept of "swimming pressure". This was accomplished by means of acoustic trapping of active matter with John's student, Sho Takatori (Nature Comm. 2016). His collaboration with Pier Luca Maffettone and Chris Macosko resulted in a very nice demonstration of using rheology to quantify dispersion stability in nanocomposite materials (JoR 2007).

Jan was raised in the Belgian village of Bonheiden by his father, who was an electrochemist and university professor,

and his mother, who still operates a lace school and museum in town. I highly recommend visiting this phenomenal museum. His mother has relayed many stories to Jan's wife, Karin, about Jan's earliest ventures in rheology. This one is especially revealing: "when he was about 10 years old, his mom found strange little plastic bags in the freezer. They contained a weird suspension and, when she asked Jan what was in them, he mentioned that it was 'snowball glue'. He had mixed snow with glue in order for the snow to stick better together (and he was sure all of his friends would be super excited once it would work)!".

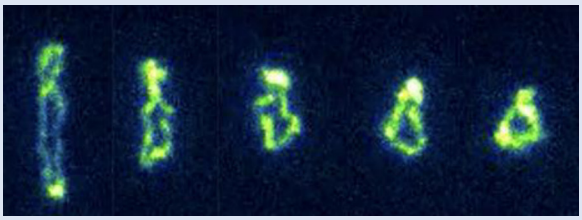
Jan is a student of Belgian literature – in the form of Tintin and Asterix comic books. Although there is no question that Tintin is (was) an adventurous Belgian boy, Jan is only too happy to rise in defense of the assertion that the famous Gaullist warrior, Asterix, is of Belgian and not French origin. Jan's father was an avid sailor and passed this passion onto Jan. Indeed, while a university student, Jan was a world-class, competitive racer (he achieved a world ranking of 30!). Favorite vacations of the Vermant family are all-hands-on-deck expeditions off the shores of Belgium and throughout the Mediterranean. Jan met his wife, Karin, while they were both chemical engineering undergraduates at KU Leuven. I have heard different stories about which person achieved the higher grades.

My wife, Mary, and I have enjoyed the company of Jan's children, and both spent a summer in our home while carrying out research internships in my laboratory. Marie graduated from KU Leuven's Faculty of Medicine and Joannes is studying pure mathematics at the same university. They are both happy to regale you with stories of Jan – like the time he put his foot through the living room ceiling while working in the attic. Joannes is also pleased to point out he is now taller than his father.

The community of rheologists is most fortunate to enjoy the leadership and scholarship of Jan Vermant. His work includes seminal discoveries that have brought understanding and fundamental insight to problems at the forefront of rheology, and he represents the qualities one seeks in a Bingham Medalist.

Special Issue on Ring Polymers

Guest Editor: Charles Schroeder, University of Illinois at Urbana-Champaign
Guest Co-Editor: Ravi Prakash, Monash University



The *Journal of Rheology* will publish a special issue on the dynamics and rheology of ring polymers. Scheduled for publication in 2022, this issue will focus on the dynamics of rings across all concentration regimes, including the melt state. We have already received a large number of high-quality submissions for this special issue. Given the interest in this topic, we are reaching out for additional contributions from experiments, theory and simulation, as well as from academia, national labs, and industry.

This special issue is planned in conjunction with a **Workshop on Ring Polymers to be held between June 22-24, 2022** at the Monash University Prato Centre in Prato, Italy (http://monash.it). The meeting is organized by J. Ravi Prakash, Burkhard Duenweg, and Charles Schroeder. The conference site is located in the beautiful Tuscany Region of Italy in close proximity to multiple cultural centers including Florence. The meeting will be sponsored in part as a CECAM event (Centre Européen de Calcul Atomique et Moléculaire); website coming soon with more details. Consider joining your colleagues for an enjoyable meeting and event!

Accepted articles will be circulated among all authors participating in the special issue and/or the meeting, for comments and questions that will be published following the article, with replies from the authors.

How to submit / Expression of intent

If you plan to submit a paper to this issue, expressions of intent are encouraged at your earliest opportunity. Alternatively, upon submission, please indicate in your cover letter that your article should be considered for the special issue.

- Expressions of intent can be sent to Ania Bukowski, Editorial Assistant, by e-mail to **JOR-EditorialOffice@aip.org**
- Use **INTENT - Special Issue/Ring Polymers** in the subject header of your message.
- Indicate a tentative title for your manuscript.
- Include contact author's name, institution and email, and those of known or proposed co-authors.
- For additional inquiries, please feel free to contact the guest editors.

DEADLINE FOR SUBMISSIONS: **November 30, 2021**

2020 Metzner Award Winner: Arezoo Ardekani

—Jeff Morris

Arezoo Ardekani, Professor of Mechanical Engineering at Purdue University, is the recipient of the 2020 SOR Arthur Metzner Early Career Award. Arezoo's research addresses complex fluids, biological flows, suspensions, active matter and transport of particles and cells. Through computational simulations, theoretical analyses, and experiments, her research deepens understanding of i) the transport of particles and microorganisms in density-stratified environments found in oceans and lakes, ii) the motion of particles and microorganisms in complex fluids, and more recently iii) complex fluids through porous media.

Arezoo received her B.S. from Sharif University of Technology in Iran in 2003, and M.S. and PhD in 2005 and 2009, respectively, from the University of California Irvine under the supervision of Professors Daniel Joseph and Roger Rangel. Her PhD work focused on particle interaction, deformation, and collision in viscous and viscoelastic fluids. After graduation, Arezoo joined MIT Mechanical Engineering as a Shapiro postdoctoral fellow. At MIT, her research focused on the dynamics of bead formation, filament thinning, and breakup in viscoelastic jets with Professor Gareth McKinley; she showed her versatility, as she also collaborated with Professors Roman Stocker and Tom Peacock on density-stratified fluids problems. After her postdoc, Arezoo joined the University of Notre Dame as the O'Hara Assistant Professor of Aerospace and Mechanical Engineering in 2011 and subsequently, Purdue School of Mechanical Engineering in 2014. In the summer of 2016, she was a visiting professor at the Institut de Mécanique des Fluides de Toulouse.

A Fellow of ASME (2020), Arezoo has received a number of awards during her faculty career. These include the Society of Engineering Science Young Investigator Medal (2020), and the Sigma Xi Mid-career Research Award (2020). Arezoo received an NSF CAREER Award (2012), and was honored with the Presidential Early Career Award for Scientists and Engineers (PECASE) in 2016. At Purdue, she has received the College of Engineering Faculty Excellence Awards for Graduate Student Mentorship (2020) and Early Career Research (2019), and she was named a Purdue University Faculty Scholar (2020-2025).

Arezoo has pioneered study of swimming in densify-stratified fluids with crucial environmental applications. Her research demonstrated that density variations encountered by organisms at pycnoclines, regions of sharp vertical variation in fluid density, have a major effect on the flow field, energy expenditure, and nutrient uptake of small organisms (J. Fluid Mech., 2019, Phys. Rev. Fluids, 2017, Scientific Report, 2015, PNAS, 2012; Phys. Rev. Lett., 2010). She has also shown that density stratification suppresses bioconvection, leading to aggregation of micro-organisms and formation of algal blooms (J. Fluid Mech., 2013, 2014, Phys. Rev. Fluids, 2017 (invited article)).

Arezoo's research has made fundamental contributions toward understanding the transport of microorganisms in complex fluids, revealing that swimming bacteria and spermatozoa, which use whip-like flagella to propel themselves, are able to increase their speed while consuming less energy because of the shear-thinning behavior of their surrounding fluid (J. Fluid Mech. 2015). She demonstrated that the thickness of bacterial flagellum is often smaller than the radius of gyration of long polymer chains, e.g. in respiratory bacterial infection. The existing theories based on continuum models fail to correctly describe bacterial motion in such cases. Ardekani has developed computational tools to overcome this limitation (Phys. Rev. Fluids 2018) and showed that as the polymer size increases, the viscosity experienced by the flagellum asymptotically reduces to the solvent viscosity, in agreement with experiment.

Ardekani also studied the collective motion of rodlike microbes in viscoelastic fluids and found that the fluid elasticity significantly reduces large scale flow structures generated by motile microorganisms generating thrust behind their bodies (Phys. Rev. Lett. 2016). This provided a framework for examination of the effects of rheological properties of the surrounding fluid and cell motility on the accumulation of microbes. Arezoo has recently launched a research program on injectable biologics, where she is investigating different aspects of their transport (Pharm. Res., 2020, Int. J. Pharm., 2020, Trends Biotechnol. 2020). Recently, her team has also begun investigating the role of roughness on the rheology of concentrated suspensions and slurries (J. Rheol. 2019 and 2020).

Ardekani is an Associate Editor of ASME Applied Mechanics Review and an Editorial Advisory Board Member of the Journal of Non-Newtonian Fluid Mechanics and the International Journal of Multiphase Flow. She is currently serving as an American Physical Society Division of Fluid Dynamics (DFD) Member at Large and DFD representative on the Irwin Oppenheim Award Selection Committee. Ardekani currently advises thirteen Ph.D. students and a postdoc. She has sgraduated seven Ph.D. students and eight M.S. students – all studying on different aspects of complex fluids and biological flows. We look forward to her contribution to the Society of Rheology for many years.

2021 Metzner Award Winner: Quan Chen

—Ralph Colby & Hiorshi Watanabe

Quan Chen, currently Professor of Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, is the recipient of the 2021 SOR Arthur Metzner Early Career Award. He has been focusing on the relaxation dynamics in miscible polymer blends and ionomers, and his combination of experiments and theory has revealed clear principles underlying complicated rheological behavior of these systems. His achievements for these materials, published in more than 80 peer-reviewed papers, have been highly appreciated in the worldwide community of rheology. This appreciation has resulted in several awards for him that include the 2016 Distinguished Young Rheologist Award from TA Instruments, the 2019 Young Researcher Award from the Society of Rheology, Japan, and this time the 2021 Society of Rheology Arthur Metzner Early Career Award.

Quan received his BS and MS degrees from Shanghai Jiao Tong University under supervision of C. Zhou in 2003 and 2007, and PhD from Kyoto University under supervision of H. Watanabe in 2011. His PhD work focused on the dynamics in miscible blends. Then, he worked on block copolymer dynamics as a postdoc with H. Watanabe at Kyoto University (2011-2012), and with R. H. Colby at Pennsylvania State University (2012-2015) to start his study of ionomers. Finally, in 2015, he moved to Changchun Institute of Applied Chemistry, Chinese Academy of Sciences as a full professor. Since then, he has been extending his research for ionomers and associative polymers (as explained below in more detail), skillfully guiding his students (7 PhD and 5 MS students in total so far), and actively serving the worldwide rheological community as an editorial board member of the Journal of the Society of Rheology, Japan and Acta Polymerica Sinica, China and as a committee member of Polymer Division, Chinese Chemical Society.

Quan is a thoughtful experimentalist – not truly a theorist but he does adeptly use models in the literature to interpret his data in interesting and insightful ways and further develop/advance those models for whatever he is studying. Moreover, he thinks of what to try on his own and solves problems clearly and quickly with the aid of his strong background in polymer physics. He started showing this outstanding capability of research when he was in the PhD course and studying component dynamics in miscible blends polyisoprene (PI) and poly(*p-tert* butyl styrene) (PtBS). PI has the so-called type-A dipole parallel along the chain backbone, but PtBS does not. He focused on this characteristic feature of the PI/PtBS blends to design state-of-the-art experiments combining viscoelastic and dielectric methods, the latter selectively detecting the large-scale motion of PI in long time scales, and successfully separated the motion of PI and PtBS components in the blends (*Macromolecules* **2008**, *41*, 8694; *ibid.* **2011**, *44*, 1570; *Polymer J.* **2012**, *44*, 102). For low molecular weight (low-*M*) PI/PtBS blends, he found that the concentration fluctuations of PtBS introduce a distribution of relaxation times for the faster PI component. For high-*M* blends, he revealed that the entanglement length a, being common for PI and PtBS in the blend, is described by a blending rule utilizing the number fractions of respective Kuhn segments as the weighing factors. He related the validity of this blending rule to a large asymmetry (large difference in the chain bulkiness) of PI and PtBS. Furthermore, he found that the motion of PI chains on length scales larger than a is retarded by the high friction component PtBS, and that the Rouse relaxation over the length scale $< a$ masks the entanglement plateau when this retardation becomes significant at low temperatures. These findings added novel aspects to our understanding of the dynamics in miscible blends of entangled polymers.

Quan kept showing his outstanding research capability in his PD study on ionomers at Pennsylvania State University. In ionomer melts having nonpolar backbones, ions very rarely fully dissociate and instead dissociate from ionic clusters as ion pairs with large dipoles. The time scale of ion pair dissociation for nonpolar ionomers is quite slow and controls the terminal viscoelastic relaxation. This slow relaxation itself has been well recognized for a long time, but the correlation between the slow relaxation and the dynamic association/dissociation of the ionic groups (behaving as stickers) was not fully elucidated. For this problem, he examined dielectric behavior of PEO-based ionomers having SO_3Na groups and revealed, for the first time, the dielectric relaxation reflecting the sticker dissociation from the cluster (*J. Rheol.* **2013**, *57*, 1441). Furthermore, he evaluated the number density of the sticky Rouse segments from the chemical composition of the ionomers to find that the onset frequency for the terminal viscoelastic relaxation agrees with the frequency of the dielectric relaxation reflecting the sticker dissociation. This finding unequivocally proved that the sticker dissociation is the trigger of the slow terminal relaxation of ionomers, and thus had a distinct impact on the polymer rheology community.

Ionomers are viscoelastic fluids on long time scales but still behave as gels in short time scales where the ionic groups have not yet dissociated from their clusters; they are thus reversible gels. Taking this molecular view, Quan theoretically predicted that the gelation occurs when the number of effective crosslinks (i.e.,

ionic groups) per chain, p, increases to a critical value $p_c \cong 1$ (*Macromolecules* **2015**, *48*, 1221; *ibid*. **2016**, *49,* 3936). He confirmed this prediction from viscoelastic data of Bob Weiss on a series of ionomers having various p. In particular, for sols having $p < p_c$, he confirmed the prediction that an increase of p results in a "Ginzburg transition" from an overlapping sol composed of many short sol chains sharing their pervaded volumes to a non-overlapping sol wherein a few, large sol chains having multiple branches are isolated from each other. For the gels, he confirmed the other prediction that an increase of p leads to the second "Ginzburg transition" from a scarce gel network (with no overlapping between long, scarce strands of the network) to a dense network (wherein short strands are heavily overlapping). Quan's findings have brought significant progress in our understanding of the ionomer dynamics as well as of the sol-gel transition in a variety of materials.

After he moved to Changchun Institute of Applied Chemistry, Quan further conducted extensive additional research for ionomers and related materials on the basis of the above finding. He demonstrated that the viscoelastic data of ionomers are well described by the sticky Rouse model utilizing the dielectrically evaluated dissociation frequency as a reciprocal of the time constant τ_s of the dissociation process in the model (*Macromolecules* **2016**, *49*, 9192; *J. Rheol.* **2017**, *61*, 1199). He also found that this τ_s and the relaxation time of the monomeric segment τ_0 satisfy a relationship, $\tau_s/\tau_0 \cong \exp(E_a/RT)$ with E_a = 8-13 kJ/mol. This relationship suggests that the sticker dissociation requires cooperative motion of monomeric segments, which adds a novel aspect to our understanding of the ionomer rheology. Furthermore, on the basis of that relationship, he successfully designed ion-containing model polymers exhibiting various rheological properties well-tuned by the medium polarity (*Macromolecules* **2017**, *50*, 963). His perspective article (*Soft Matter* **2018**, *14*, 2961), summarizing all those findings, serves as an excellent guide for future research and is highly appreciated in the rheology community. Very recently, he extended his study to telechelic ionomers to reveal that the ionomers exhibit ductility when flow-induced dissociation of an ionic cluster is followed by quick re-association into another cluster (*Macromolecules* **2018**, *51*, 4735). For telechelic ionomers with having more than one ionic group at each end of the chain, he also demonstrated a cooperative feature of the dissociation of those groups (*Macromolecules* **2019**, *52*, 2265; *ACS Macro Letters* **2020**, *9*, 917).

In summary, the outstanding research ability of Quan Chen has enabled him to reveal novel features of miscible blends and ionomers thereby making remarkable progress in our rheological understanding of these materials. We are fully convinced that he will continue developing new ideas about the dynamics of polymer-based materials, leading the worldwide community of rheology for many years to come.

Using rheology and mathematical modeling for understanding the role of performance polymers in lubrication

Eugene Pashkovski, Reid Patterson, Dan Knapton, *the Lubrizol Corporation*, and Ilya Kudish, *ILRIMA consulting, LLC*

Modern trends in the automotive industry demand increasing efficiency of engine oils used for lubricating different components of internal combustion engines. Even small increases in fuel economy multiplied by millions of car engines can be quite significant in reducing carbon dioxide emissions worldwide [1]. For estimating the efficiency of lubricants, specific standard tests were developed to determine fuel economy increase (FEI) [2]. The efficiency of engine oils is associated with the reduction of frictional losses in boundary, mixed and hydrodynamic regimes of lubrication occurring in different parts of engines. Most significant energy losses (~40%) originate from piston rings moving within the cylinders [2]. Reciprocal motion of the piston within the cylinder suggests that the hydrodynamic regime of lubrication prevails at the central part of cylinder where linear velocity of the piston reaches the maximal value, whereas boundary lubrication occurs near so-called dead zones. There are specific methods to reduce boundary friction using low-molecular weight additives that form tenacious tribofilms [3], whereas the hydrodynamic friction may be reduced by adjusting the rheological properties of oils.

The rheology of oils can be controlled by specific polymers, including linear polymers, stars, block copolymers, etc. These polymers are traditionally used to reduce the temperature dependence of viscosity [4]. However, as was first pointed out by A. Lodge [5], the *elasticity* of polymer-containing oils can help in improving fuel economy. Significant friction reduction for polymer-containing oils in journal bearings was observed in carefully designed experiments [6]. Normal stresses, the signature of polymer elasticity, generate additional lifting forces that are proportional to the first normal stress difference N_1. This effect depends on the first normal stress coefficient $\Psi_{1,0} \sim \lambda \cdot \eta_p$ [7], where λ is the characteristic relaxation time of polymer solution and η_p is the polymer contribution to viscosity.

As λ and η_p both depend on polymer molecular weight M_w, it would be plausible to have high M_w for increasing elasticity and fuel economy. However, conventional engine oils contain relatively short (Mw ~ 100,000) chains at concentrations below the critical overlap concentration c^* so that the elasticity of solutions is relatively weak. This makes the direct measurements of N_1 under shear flow quite difficult.

In addition, the measurements of N_1 under shear may not correctly represent actual flow patterns within the tribological zone. The streamlines computed for both, Newtonian and non-Newtonian fluids have complex configuration at the narrowing contact zone [8] suggesting the presence of extensional flow. As macromolecules can be fully stretched in the extensional flow field, the elastic forces are expected to exceed those generated under homogeneous shear flow. The extensional relaxation time λ_E may exceed the time λ_s obtained using oscillatory shear by one order of magnitude [9], and this effect is quite pronounced for weakly elastic polymer solutions [10]. This makes extensional rheology methods quite suitable for investigating weakly elastic engine oils.

In this paper, we show that the extensional viscosity and relaxation time of the non-Newtonian lubricants can be associated with measured FEI according to standardized engine testing [2]. Prior to discussing extensional rheology, we demonstrate that the oils under study have nearly identical shear viscosity. To cover the shear rate range 10^0-10^7 s^{-1}, three different instruments i.e. ARES G2 (TA Instruments), hts-VROC (Rheosense), and USV (PCS Instruments) were used (see Fig. 1). The viscosity data measured at T = 80 °C can be approximated by the unique Carreau-Yasuda fit with zero and infinite shear rate viscosities η_0 = 0.013 and η_s = 0.008 Pa·s, respectively. In engines, the shear rate can be as high as 10^6-10^8 s^{-1}, so the viscosity of oils is close to the lower viscosity limit η_s.

Following the arguments of Lodge [5], the efficient oils must possess high elasticity at low shear viscosity. Thus, the ratio of extensional viscosity to shear viscosity or Tr ratio ($Tr = \eta_E/\eta_0$) can be used as the rheological parameter associated with fuel economy. The most convenient method for measuring transient extensional viscosity is based on the analysis of visco-elasto-capillary flow realized in Capillary Breakup Extensional Rheometer (CaBER, Thermo Electron). The addition of video imaging with ultrafast camera (Fastcam S4, Photron) and *Edgehog* image analysis software [11] allows for the determination of the mid-diameter of fluid bridge D_{mid} with the resolution of ~2 µm/pixel. In order to maintain the symmetrical shape of liquid bridges, a slow retraction method (SRM) [12] was used with the upper plate of the rheometer (D_0 = 4 mm) moving at small speed v = 0.11 mm/s until the liquid bridge becomes unstable and the capillary thinning process is recorded at high speeds from 3000 to 25000 fps. A set of images shown in Fig. 2 demonstrates axially symmetric thinning profiles with minimized inertial effects.

The contribution of inertia to capillary thinning can be characterized using the

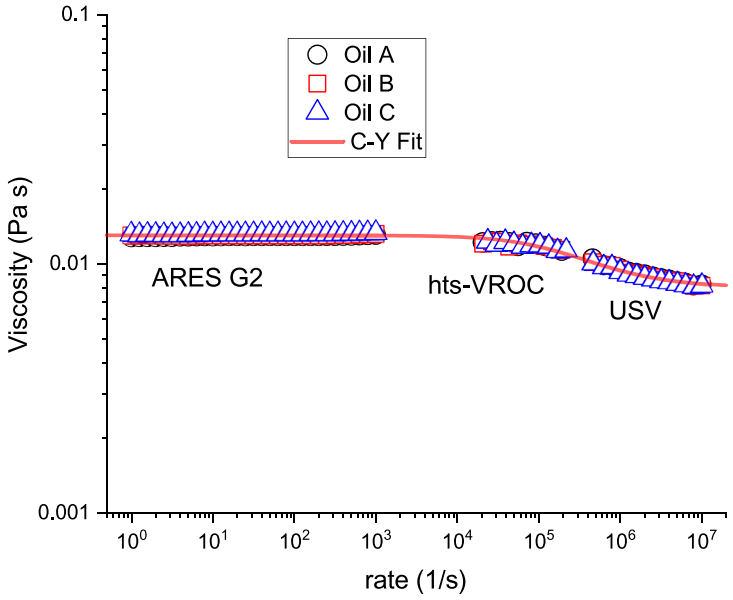


FIGURE 1. Dependences of shear viscosity for 3 engine oils on shear rate measured using ARES G2 (TA Instruments), hts-VROC (Rheosense) and USV (PCS Instruments) at T = 80 °C. Solid line represents the Carreau-Yasuda fit.

Ohnesorge number, which compares viscous and inertial effects in capillary thinning, $Oh = \eta_0/(\rho R_0\gamma)^{1/2}$; the critical value of $Oh_c = 0.2077$ [12] sets the low limit of fluid viscosity for CaBER experiments. In this report, we analyze extensional flow of oils with η_0 ~0.1 Pa·s and surface tension $\gamma = 30$ mN/m; the Ohnesorge number $Oh = 0.45$ exceeds Oh_c, i.e. that the fluid inertia can be neglected.

The time dependencies of the mid-diameter of the fluid bridge $D_{min}(t)$ are shown in Fig. 3a; these dependences are shifted along the time axis so that t = 0 corresponds to the maximum strain rate $\dot{\varepsilon} = (-2/D)dD/dt$ (Fig. 3b). The observed maximum of $\dot{\varepsilon}(t)$ precedes the transition to the elastocapillary (EC) regime where $D_{min}(t)$ obeys the exponential function [10]:

$$\frac{D(t)}{D_0} = \left(\frac{D_0 G}{4\gamma}\right)^{1/3} \exp\left(-\frac{t}{3\lambda_E}\right) \quad (1)$$

Here, D_0 is the diameter of liquid bridge at the beginning of the EC regime, $G = nk_BT$ is the elastic modulus of polymer solution, n is numerical density of polymer chains, and k_B is the Boltzmann constant. Three engine oils were formulated at approximately similar polymer contribution to viscosity η_p or $[\eta]c$, but different Mw of polymers. As a result, the oils with the same shear viscosities have very different breakup times and the time interval of EC thinning. The EC thinning occurs at constant strain rate necessary to maintain the elastocapillary balance so that the increasing capillary stress is compensated by the polymer stress. In this case, the Weissenberg number $Wi = \dot{\varepsilon}\lambda_E = 2/3$; therefore, for Oil C that have the longest λ_E, the strain rate is the lowest one.

The elastocapillary number that compares the time scales of EC to purely viscous thinning $E_c = 2\lambda_E\gamma/(\eta_s D_0)$ is a natural choice for extensional flow experiments and can be associated with FEI. As was mentioned before, the Trouton ratio ($Tr = \eta_E/\eta_0$) can be used for the same purpose. The apparent extensional viscosity calculated from

$$\eta_E^{app}(t) = -\frac{\gamma}{dD_{min}/dt} \quad (2)$$

is shown in Fig. 3c as a function of Hencky strain $\varepsilon_H = \ln[D_0/D(t)]$. At $\varepsilon_H = 4$, η_E^{app} increases for engine oils before it reaches the plateau that corresponds to the increasing strain rate at end of EC regime (Fig. 3b) similar to that in the purely viscous regime. That is, the maximal elastic force developed from fully stretched chains is insufficient for maintaining the capillary stress that increases with decreasing the filament diameter. In this regime, according to FENE-P model [13] the extensional viscosity reaches the maximum value $\eta_E^{max} = 2Gb\lambda_Z$ (here λ_Z is Zimm's relaxation time and $b = L^2/\langle R_0^2\rangle$ is stretching parameter (L is the fully stretched chain length and $\langle R_0^2\rangle$ is the mean square radius of the unperturbed chains). The parameter b scales with the number of Kuhn segments of polymer chain N_K as $b \sim N_K^{2(1-\nu)}$ [14] and can be quite high ($0.5 < \nu < 0.585$ is the excluded volume parameter). As the shear viscosity of oils $\eta_0 = G\lambda_Z$, the maximal Trouton ratio depends on N_K as $Tr^{max} = \eta_E^{max}/\eta_0 \sim N_K^{2(1-\nu)}$. The value of Tr^{max} can be obtained from the plateau viscosity values ($Tr^{max} = \eta_E^{max}/\eta_0$) (see Fig. 3c).

The rheological parameters measured at T = 25 °C (Table 1) demonstrate that the oils have noticeably different values of Tr^{max}, λ_E, and E_c number although the

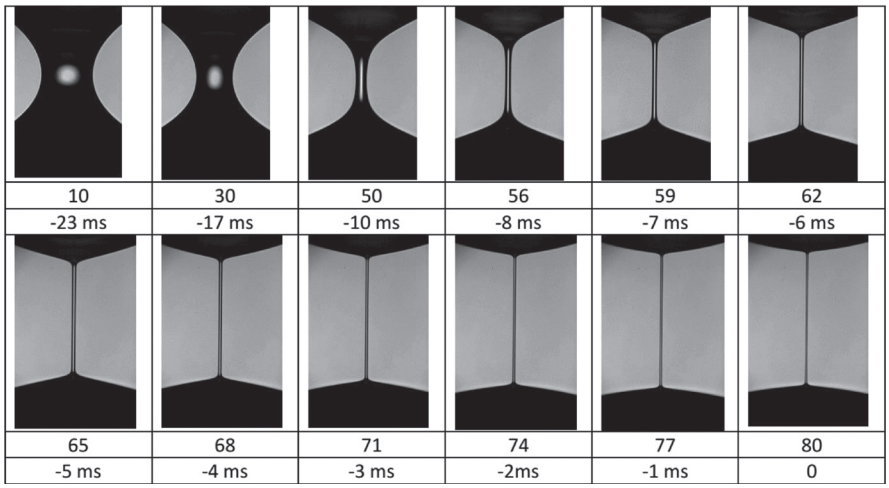


FIGURE 2. Images of capillary thinning for engine oils obtained using slow retraction method recorded at 3000 fps.

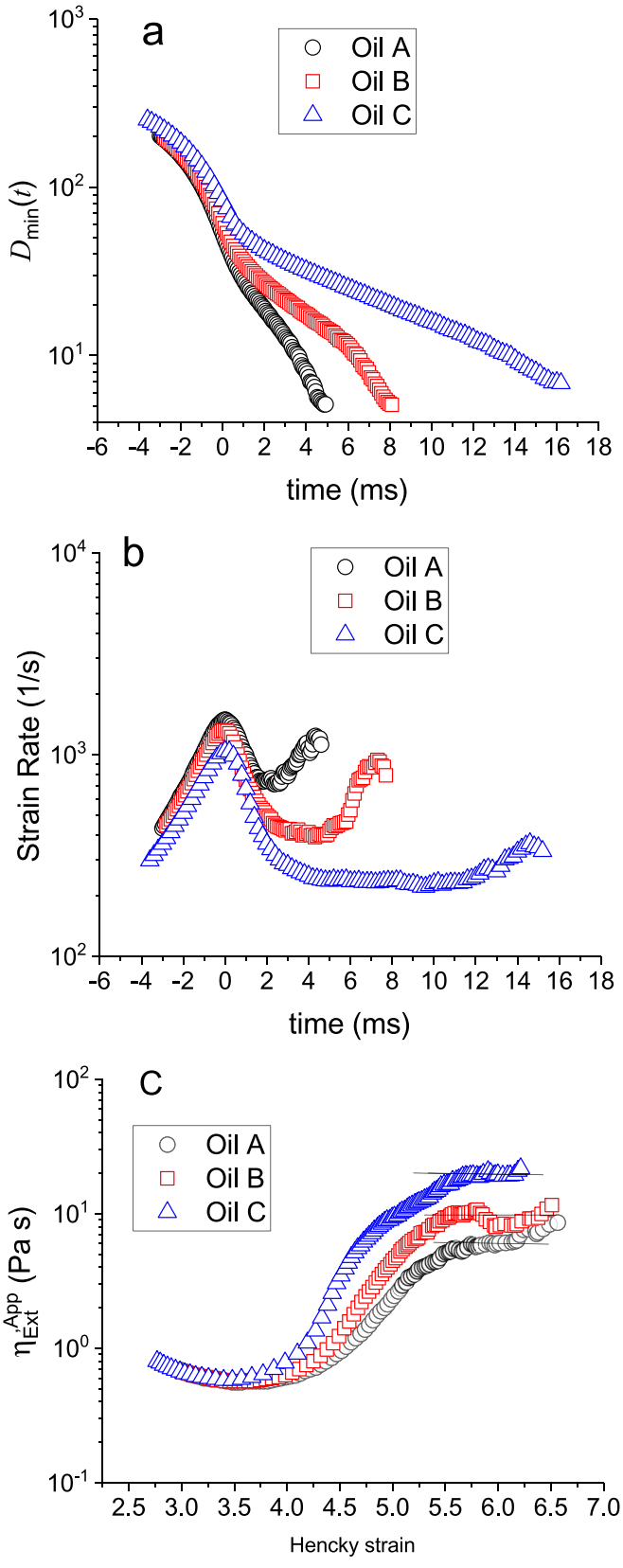


FIGURE 3. Time evolution of mid-diameter of fluid bridge (a), strain rate (b) for engine oils (T = 25 °C). (c) Dependences of apparent extensional viscosity η_E^{App} on Hencky strain. Horizontal bars indicate the plateau values of η_E^{App}.

values of shear viscosity η_0 are the same. Remarkably, the values of FEI estimated in real engine tests according to the automotive standard [2] increase with Tr^{max} and/or E_c number as shown in Fig. 4. This result indicates that the mechanism of energy saving in the hydrodynamic regime of lubrication is directly associated with the elasticity of engine oils. For the piston ring-liner contact, the lubrication regime is predominately hydrodynamic; therefore, it is reasonable to evaluate viscous losses in the ring-liner contact.

Modeling hydrodynamic lubrication for non-Newtonian fluids represents certain challenge. The selection of constitutive equations for investigating the effect of elasticity on tribological parameters is limited to relatively simple constitutive equations. The example of polymer effect on hydrodynamic lubrication using upper convected Maxwell model [15] demonstrates that the additional pressure originating from polymer elasticity can be accounted for using the perturbation method where the non-Newtonian stress term is proportional to *De* number defined as $De = \lambda U/l$, where U is the characteristic velocity of fluid within the tribological zone of length l. This approach is valid for $De << 1$, and may be not applicable for $De \sim 1$. In this paper, the analytical approach developed in [8] was used along with the Oldroyd-B constitutive equation in the form described in ref. [7]. The obtained Reynolds-like equations describing hydrodynamic lubrication were solved numerically for computing contact tribological parameters and quasi-steady viscous energy losses.

For modeling the process of lubrication, the piston ring is represented by an infinite cylinder moving along infinite plane (Fig. 5) with speed $u(\theta)$. The vertical load $P(\theta)$ was approximated by the Lorentzian function that corresponds to the pressure measured as a function of the crankshaft angle θ of a small diesel engine used in a passenger car. Using Oldroyd-B constitutive equation [7], viscous (τ_{21}) and elastic (τ_{11}, τ_{22}) stresses can be computed within the gap between the piston ring and the cylinder. Thus, contact tribological parameters and viscous energy loss (*EL*) associated with hydrodynamic lubrication can be calculated for a piston ring of radius R for each a fixed crankshaft angle θ:

$$EL|_{\theta=const} = 2\pi R \int_{X_i}^{X_e} \eta\dot{\gamma}^2 dX \qquad (3)$$

TABLE 1. The values of η_E^{max}, Tr^{max}, λ_E, and E_c number for engine oils at T = 25 °C.

	η_E^{max}	Tr^{max}	λ_E	E_c	η_0
	Pa·s	-	ms	-	Pa·s
Oil A	6.1	56	0.92	0.13	0.103
Oil B	9.8	92	1.61	0.23	0.103
Oil C	19.5	189	2.9	0.42	0.106

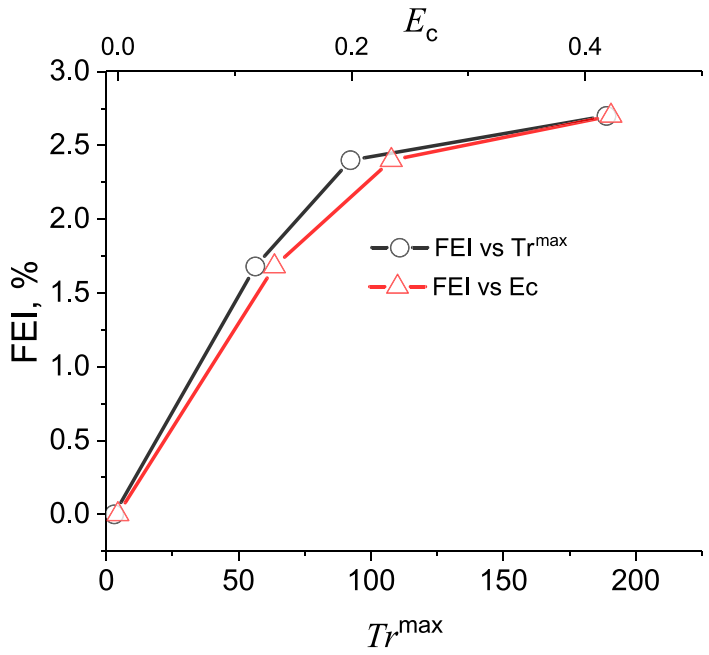


FIGURE 4. Dependences of FEI on Tr^{max} (circles) and E_c number (triangles) for a Newtonian oil ($Tr = 3$, $Ec = 0$) and viscoelastic engine oils listed in Table 1).

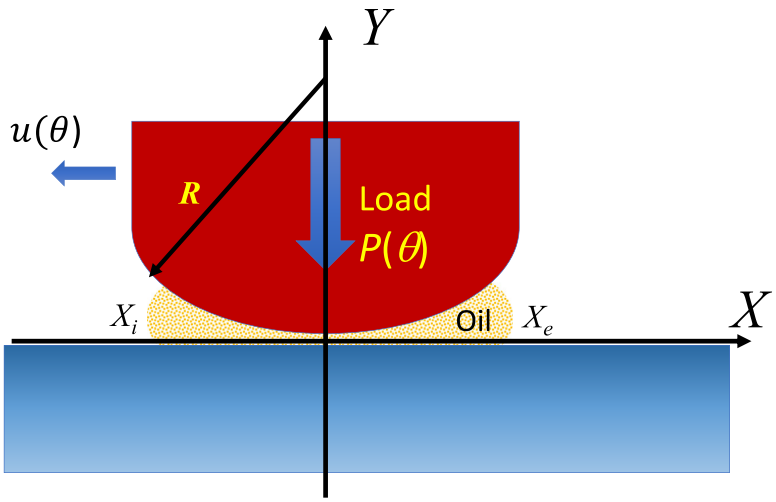


FIGURE 5. Piston ring is represented by a cylinder of radius R moving along the infinite plane with velocity $u(x) = u_0 \sin(\omega t)$. The variable load changes in the combustion cycle.

where X-axis corresponds the piston velocity direction and X_i and X_e are the contact inlet and exit coordinates as shown in Fig. 5. The MATLAB code was written to solve the equations describing the motion of lubricants within piston ring-liner contact at conditions close to that in real engine operation (2000 RPM). The flow in the contact zone is not purely extensional; therefore, it is necessary to estimate the relaxation time measured under shear. It can be estimated from the ratio of first normal stress N_1 and the polymer shear stress $\tau_p = (\tau_{21} - \dot{\gamma}\eta_s)$ as described in ref. [16] using White-Metzner model. We have found a linear relationship between the relaxation times measured at T = 5-25 °C in extensional and shear flows, $\lambda_E = 9.17\lambda_{N1}$, which is consistent with other measurements [8,9]. For estimating relaxation time at high temperature (T = 80 °C), we use the temperature dependence of solvent viscosity. In our calculations of viscous energy losses, we use $\lambda_1 \sim 0.11\lambda_E$, η_0 and η_s listed in Table 2:

The dependences of viscous energy loss calculated for these oils as a function of crankshaft angle (Fig. 6.) have shape typical for power losses measured in real engines for the combustion cycle [17]. Note that the peak value of energy losses systematically decreases with increasing Tr_{max}. This decrease is due to the additional pressure associated with the presence of polymer chains in oils. The coupling between the hydrodynamic pressure $p(X)$ and the fist normal stress difference N_1 demonstrates the effect of λ_1 on $p(X)$ as shown in Fig. 7 where $p(X)$ and $N_1(X)$ are plotted for $\theta = 70^0$ that approximately corresponds to the crankshaft position of the maximum energy loss. The coordinate $X = 0$ is chosen at the minimal gap, and the grey area indicates the space filled with the lubricant. Interestingly, the oil elasticity does not affect $p(X)$ at the entrance or inlet zone ($X_i \sim X << 0$) because, due

TABLE 2. The relaxation time λ_1 and viscosities η_0 and η_s used for computing viscous energy loss.

	η_0	η_s	λ_1
	mPa·s	mPa·s	μs
Oil A	10.3	8	12.64
Oil B	10.3	8	22.15
Oil C	10.3	8	39.89

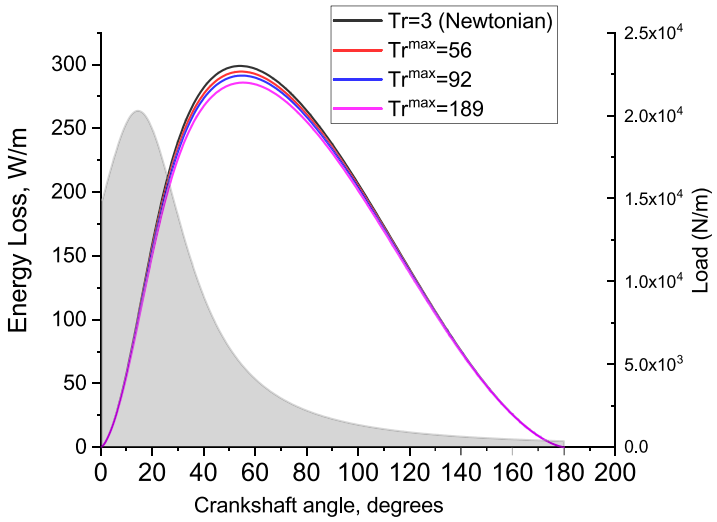


FIGURE 6. Dependences of viscous energy loss on crankshaft angle in hydrodynamic lubrication regime for engine oils with different Tr ratios at T = 80 °C at angular velocity 2000 RPM.

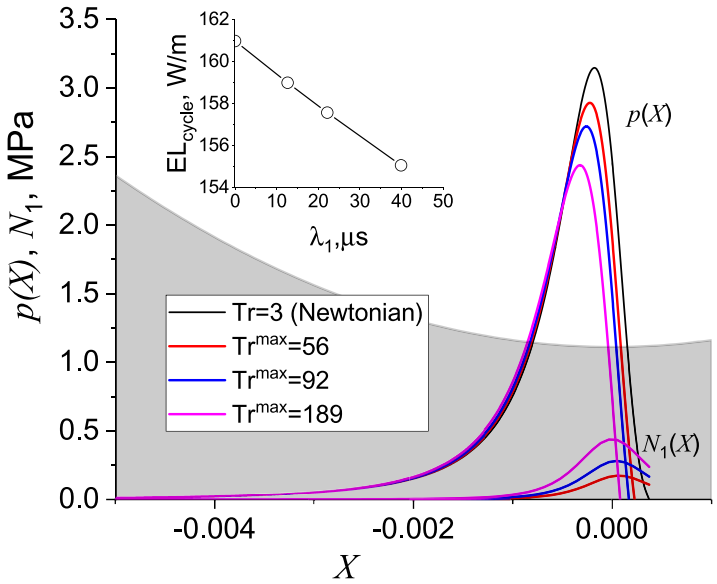


FIGURE 7. Dependences of $p(X)$ and $N_1(X)$ for oils with different Tr ratios; The peak values of $p(X)$ decrease, and those for $N_1(X)$ increase with increasing Tr ratios. The inset shows decreasing energy loss with increasing relaxation time.

to the large gap, the shear rate is relatively small. However, when the channel narrows down and the shear rate increases, the growing contribution of $N_1 = 2\eta_0\lambda_1(\eta_0\text{-}\eta_s)\dot{\gamma}^2$ causes the hydrodynamic pressure to reduce. The inset in Fig. 7 shows that the integrated energy loss calculated for the combustion cycle decrease significantly with increasing λ_1. Thus, the mathematical modeling of hydrodynamic lubrication for an Oldroyd-B fluid result explains the experimental dependence of FEI for the same oils. However, the dependence of FEI vs Tr ratio shown in Fig. 4 deviates from being linear for $Tr > 100$, which is explained by the progressive degradation of long-chain polymer during engine tests. Therefore, increasing Tr ratio for regular engine oils above Tr = 100 engine oils may not lead to significant values of FEI. However, highly elastic oils with Tr > 100 may be practical for certain type of applications, for instance for car racing, where fresh oils are used for a short period of time, typically for just one race.

Conclusion

The major function of polymers used in engine oils is to reduce the dependence of viscosity on temperature. In addition, certain polymers may change the flow characteristics in hydrodynamic lubrication regime. Even a small amount of polymer in engine oils may be sufficient to generate normal stresses within the tribological zone. Capillary breakup extensional rheology is quite suitable for probing the elasticity of engine oils. Ultrafast video imaging of thinning fluid bridge allows one to analyze the dynamics of visco- capillary and elastocapillary thinning and determine rheological parameters that may be associated with energy efficiency.

Remarkably, we found that large values of Tr ratio and Ec number can be correlated with decreasing fuel consumption in a standard sequence of engine fuel economy testing. To explain this behavior, a special tribological model was developed based on Oldroyd-B rheology. This model was used to compute viscous energy losses for piston ring-cylinder liner contacts. The energy losses were found to decrease progressively with increasing relaxation time; this effect was further investigated by calculating the dependences of hydrodynamic pressure and the first normal stress difference N_1; it was found that the hydrodynamic pressure decreases while N_1 increases with relaxation time of engine oils.

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The Society of Rheology Mission Statement

Our Vision

An international community of rheologists working towards common goals as articulated in our founding Constitution.

Values

We are the nexus of excellence in the theory and practice of rheology. We are committed to advancement and promotion of the rheological sciences and practice of rheology broadly across diverse groups of individuals, disciplines and industries.

Mission

We aim to expand the knowledge and practice of rheology through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what rheology is, and how it impacts humanity and the world.

– Adopted by the SoR Executive Committee, 10 June 2017

Secretary's Report

By Kal Migler

Minutes of the Society of Rheology Fall 2020 Executive Committee (Excomm) Meeting, November 1, 2020, via WebEx

Attendees:

SOR Executive Committee

Mike Graham	President
Anne Grillet	Vice President
Norm Wagner	Past President
Chris White	Treasurer
Kalman Migler	Secretary
Ralph Colby	Editor
Anke Linder	Member at Large
Jonathan Rothstein	Member at Large
Marie-Claude Heuzey	Member at Large
Jennifer Mills	Student representative

Other SOR participants

Albert Co	Webmaster, Local Arrangements — Bangor
Kelly Schultz	Diversity, Equity, and Inclusion Committee
Andy Kraynik	Meetings Committee
Gordon Christopher	Membership Committee
Maryam Sepehr	Education Committee
Roger Bonnecaze	Local Arrangements — Austin
Simon Rogers	Local Arrangements — Chicago
Gerry Fuller	ICR, International outreach

AIP and AIPP participants

Liz Dart Caron	AIP
Joe Castellano	AIPP
Bridget D'Amelio	AIPP

President Mike Graham called the meeting to order at 10:02 AM (Central), welcomed guests and stated the Mission, Values, and Diversity, Equity, and Inclusion statements of the Society of Rheology.

Reading of motions passed between Spring 2020 and Fall 2020 ExComm meetings:

1. **Motion** approving the following members as **Society Fellows** decisions, passed by unanimous email vote of Executive Committee on 07/29/2020:
   - Prof. Lynden A. Archer (Dean of Engineering, Cornell University)
   - Prof. Surita R. Bhatia (Department of Chemistry, Stony Brook University)
   - Dr. William H. Hartt (The Procter & Gamble Co.)
   - Prof. Savvas G. Hatzikiriakos (Department of Chemical and Biological Engineering, The University of British Columbia)
   - Prof. Saad A. Khan (Department of Chemical and Biomolecular Engineering, North Carolina State University)
   - Prof. Gregory B. McKenna (Department of Chemical Engineering, Texas Tech University)

Minutes: A need for a correction to the minutes from the June 21, 2020 meeting, as distributed to membership via email, was noted. The distributed email incorrectly listed the years of the prior and current Executive Committee meetings. A motion to accept the corrected minutes was seconded and passed by unanimous approval.

Diversity and Inclusion

- Kelly Schultz presented a proposal on how to handle **harassment** claims at SOR events, such as meetings. In this proposal, the SOR President and Vice President would be responsible for the real-time handling of such claims at events. The HR department of AIP would be on call for guidance and can later be called upon to assist in a formal investigation. Discussion included what kind of training and guidance can be provided to the President and Vice President to carry out this responsibility. The consensus was that more discussion and study is warranted, which is feasible given the time available before the next in person meeting.
- **Rheology Research Symposium (RRS)** The RRS is a student symposium held the weekend before the annual meeting. There is one year remaining on the **Venture Partnership Fund** with AIP, which is funding it. The intention is to run a second RRS at the Bangor 2021 meeting, based on its success at the NC meeting in 2019. If the SOR is

to continue the RRS after the two years of AIP funding, it must cover the costs.
- We had voted at Spring 2020 to bring to the membership the proposal to make Diversity, Equity, and Inclusion a standing committee. We will move forward with this and bring it to the membership for a vote.

AIP update — Liz Caron

- Liz Caron described their new **AIP Diversity Office**, which has two new hires: Taharee Jackson, and Arlene Modeste Knowles. It will work within AIP itself and with the member societies. The AIP Board established a $200k diversity action fund and established the Joseph A. Johnson III Award for Excellence to recognize first rate Black scientists devoted to mentoring students and early career scientists. She described the AIP National Task Force to Elevate African American Representation in Undergraduate Physics & Astronomy (TEAM-UP). The task force recommends establishment of a $50M endowment to support this.
- **Future of Associate in Convening: Envisioning for the Sciences (FACETS)** Liz Caron described discussions to envision the future scientific meetings, especially given the lessons of the pandemic. On-line approaches can increase participation and be of benefit to both early career and developing world scientists.

European Society of Rheology Update — Anke Lindner

- The Annual European Rheology Conference (AERC) 2021 will be held virtually in April. AERC 2022 will be in April in Sevilla, Spain. In Summer of 2023, the ICR will be in Athens. AERC 2024 will be held in Leeds, England.

Meetings Committee Anne Grillet, Andy Kraynik, Roger Bonnecaze, Simon Rogers, Gerry Fuller, Albert Co, Marie-Claude Heuzey

- **ICR Updates** Gerry Fuller, Marie-Claude Heuzey. If the SOR decides not to hold annual meetings during ICR years, then SOR needs to hold an awards ceremony at the ICR. This has been arranged for the virtual 2020 ICR meeting and for the Athens 2023 meeting. The upcoming virtual ICR in December 2020 looks healthy with 800 submissions. SOR will not hold a business meeting at the ICR. We will need a separate virtual meeting. The hotel money that SOR sent for the cancelled in-person Brazil meeting is supposed to be reimbursed in a year, in Brazilian currency.
- **Bangor 2021, Fall,** Albert Co. The Convention Center contract has been signed; if sufficient notice is given, our financial exposure is manageable. We do not have any hotel contracts. Discussion about the date by which a decision needs to be made regarding an in-person, virtual or hybrid meeting. Decision must be before submission of abstracts in May. The Technical Program got transferred from the cancelled Austin Winter meeting.
- **Chicago 2022, Fall** Simon Rogers. The dates of October 2-6 conflicts with Yom Kippur (Tuesday evening through Wednesday), and so the Bingham Banquet will be on Monday night. There is a projected budget deficit, and so a concerted effort for sponsorship is underway. There will be an Art Institute event on Tuesday night. Program Chairs are Charles Schroeder and Emanuela Del Gado.
- **Austin 2024, Fall,** Roger Bonnecaze. Cancellation of the Winter 2021 meeting exposed the SOR to a potential liability of $250k. Fortunately, the contract was renegotiated to Fall of 2024. However, the hotel will not allow the date to be set until April 2023. It will be either the week of October 6th or October 13th.
- **Future Meetings,** Andy Kraynik. Discussions for 2025 with Travis Walker regarding a meeting in Rapid City, SD have been held. The long-term issue is that meetings are becoming more complex, and the SOR may need to engage with professional meeting planners. We would want a meeting organizer with good knowledge of the society. Question: How much would this add to the cost per registrant? Discussion to be continued at Spring ExComm.

Editors' Report, Ralph Colby. Through the pandemic, submissions have increased but it has become more difficult to find reviewers. He reported several positive trends: processing time is still decreasing, partly because about 25% of manuscripts are rejected by the editor without outside review. Post publication survey scores are 9.5/10. Published page counts were down in 2019 but increasing in 2020. Invited review articles are well cited; the JoR impact factor is 3.7.

AIPP update — Joe Castellano

- **Financials:** JOR full text downloads are behind the paywall again, following a liberalization temporarily put in place in the earlier stage of the pandemic. The digital archive sales are lower than anticipated ($24k), but the overall return to SOR via the publishing agreement will be about the same this year compared to last. There are banner ads in the journal for special topics and for joining SOR.
- **Scilights:** (https://aip.scitation.org/journal/sci) JOR had 6 Scilight articles published in 2020.
- **Diversity:** The AIPP have started a JOR gender diversity project to measure male vs. female acceptances. Also, they are examining diversity in many journal boards, noting an underrepresentation from India and China.
- **SOR Meeting Registration:** Working with Anne Grillet and Albert Co, the project for AIPP to run the registration for the SOR annual meetings is on track.

Bulletin and SOR communications — Kalman Migler, Albert Co, Norm Wagner

- **Webmaster**, Albert Co: Working on posting of remaining biographies of Bingham winners and Fellows.
- **SOR/AIP cooperation on communications**, Kalman Migler. Discussion of whether SOR should employ the AIP news feed service whose intended audience is news outlets that could write articles based off the news feed. AIP News could highlight annual meeting announcements, Bingham winners, or newsworthy talks. There is a fee for the service ($800 for a meeting announcement). The plan is to try out this service for the Bangor meeting.
- **SOR ad hoc Bulletin Committee** Norm Wagner chaired the committee; it made a set of recommendations. (See Appendix.) The Bulletin would be published one time per year and would be supplemented by a more frequently published Digest. Both would be electronic only. The Digest would allow for more timely dissemination of news, announcements

and events; its frequency would need to be determined and there would be coordination with social media platforms. Need to advertise for a position for an Editor; this position would include a stipend. Discussion emphasized the need to move rapidly.

Treasurer's Report — Chris White, Anne Grillet

- **Financial Status** - Chris White. The SOR total assets stand at ~ $2.1M, approximately the same as last year. The Raleigh meeting will end up with a $55k loss. We will have a better picture of the 2020 budget year at end of calendar year. Currently we see that interest rates and treasury bills are down. Importantly, our exposure to financial market uncertainties is very low. JOR revenue is down a little. The 2021 budget planning is underway, it will be sent out to ExComm soon. There are uncertainties within it with respect to an in-person meeting in October. Need to discuss when to present the 2021 budget to membership.
- **Financial Reserves Levels and Financial Advisement** We are awaiting recommendations from the financial advisement committee. Discussions regarding any adjustments to financial reserves (either total amount or breakdown of categories) will be deferred until such recommendation are received and discussed.
- **SOR Venture Partnership Funds** – Anne Grillet. A call for proposals was put out and two proposals were received, both funded. One is a $3k proposal for Soft Matter Kitchen by Arif Zainuddin Nelson and the second is for $7.9k (total) for student trivia nights at the next two in-person annual meetings. Jonathon Rothstein will be project manager for Soft Matter Kitchen and Jennifer Mills for the student trivia.

Membership Update – Gordon Christopher. There is a decrease in membership; at this point in the year we are at about 950 members, whereas at the end of 2019 we had about 1200 members. There has been a long-term decline in industrial members, from about 500 in 2015 to about 200 in 2020. The 3-year membership plan is working well, about 1/3 of membership uses this option. Discussion on how to re-engage lapsed members. In some cases, people may not be aware they are lapsed.

Education committee report and discussion — Maryam Sepehr

- **Short courses.** There will be two topics at the Bangor meeting. First is a 2-day additive manufacturing course taught by Jon Seppala, Michael Mackay and Patrick Anderson. There will be a demo session. It is transferred from the cancelled February 2021 meeting. The instructors prefer to give an in-person course. The second is "Colloidal gels, formation, structure and rheology" to be taught by Matt Helgeson, Roseanna Zia, and Safa Jamali as a 1.5 day course with experimental and simulation demos on Sunday. It could be in-person or online. Financially, 36 attendees in total are needed to break even. Questions include how to handle logistics in case the course needs to go on-line. Request to increase honorarium from $2100 to $2600 (split between instructors)- there has not been an increase in about 9 years.
- A **survey** to membership regarding short courses and meetings is underway.
- Discussion on ways to increase collaboration with allied societies. Modes of engagement include presentation of short courses, and sessions or booths at yearly meetings of allied societies such as SPE, MRS and TAPPI, Society of Tribologists and Lubrication Engineers, Adhesion Society.

Executive Session

Student Physics Society **(SPS)** Internships - **Motion** to authorize funds for an internship from Rheology Venture Funds to support a summer student in the Soft Matter Kitchen, subject to the availability of Arif Zainuddin Nelson to mentor a student. A motion to approve was seconded and passed by unanimous approval.

Harassment Report Process – No specific action at this meeting; awaiting further information from Kelley Schultz before voting on the proposed process.

Rheology Bulletin - Structure and Staffing.

- **Motion** to accept the recommendation of the SOR ad hoc Bulletin Committee (See Appendix). A motion to approve was seconded and passed by unanimous approval.
- **Motion** Advertise for the position "Rheology Bulletin and Digest Editor." A motion to approve was seconded and passed by unanimous approval.

Awards Process

- **Awards and Fellowships Motion:** For the Bingham, the Metzner and Fellowship nominations, the following rules apply: (i) Only one nomination per nominator; (ii) Only one new recommendation letter per recommender per year. (iii) The SOR officer who set the committee (president or past president) is prohibited from nominating or writing a letter. A motion to approve was seconded and passed by unanimous approval.
- **Fellowships:** It was noted that there are six Bingham award winners who are not SOR Fellows, and there was discussion of what effect this could have on future Fellowship nominations. No action taken at this time.

CompuFlu 2020 + 1, Norm Wagner. We were going to provide travel funds to their meeting. We will hold off this year.

Institutionalizing RRS: No action taken at this time, as it can be discussed after the next RRS.

Centennial/history Committee: Mike Graham to make this a committee in 2021.

SOR Venture Fund: It was not a good year to try the SOR Venture Fund. It would be useful to find ways to discuss this with potentially interested people at the next in-person meeting to help generate ideas. We could possibly fund RRS through this mechanism, beyond Bangor. Norm Wagner: **Motion** to re-authorize the SOR Rheology Venture Fund for one year, up to $33k. A motion to approve was seconded and passed by 8 – 1 .

Short Course Expenses (i) **Motion** to increase travel reimbursement for expenses for SOR short course up to $1600 for international instructors. A motion to approve was seconded and passed by unanimous vote. (ii) **Motion:** Increase honorarium by 21%. New honoraria would be $2100 for 2 day course; $1800 for 1.5 day course and $1400 for 1 day (to be split between 6 instructors). A motion to approve was seconded and passed by unanimous vote.

Membership: Concerns over lower membership. Seeking ideas for engaging members. Perhaps we can set up a webinar series. This would involve

cooperation between Education and Membership Committees. Mike Graham will reach out to membership committee.

Budget: We will formally present the 2021 budget to the membership at the Business meeting, and we should provide it to them in advance of that, with a means to provide comments. Normally the membership votes to accept the budget.

Next Business meeting to be held in February 2021, at a date near to when the Winter meeting would have been held.

Next ExComm meeting to be held in April 2021.

Meeting adjourned.

Appendix

Recommendations of the **ad hoc Rheology Bulletin Committee:**

1. the Bulletin remains an archival document for the society and such information of archival importance should be published yearly
2. the Bulletin should be published in electronic form only
3. It is recommended to contract with AIPP or a suitable service to provide layout and copy editing services.
4. a digital Rheology Digest should be published more frequently (coming from the Secretary of the Society by email and suggested every other month to coordinate with JOR) and contain timely information of interest to the Society and rheologists more broadly, including timely items of Society business, such as award nominations, award recipients and upcoming meetings, as well as information about career opportunities and career development, as well as paid advertisements as appropriate.
5. the Society should hire a Bulletin Editor and provide a stipend commensurate with the duties
6. the Society of Rheology Bulletin Editor should be supported by an editorial board (volunteer) to be appointed by the President consisting of no less than the following representation to insure a diverse and inclusive representation as well as gather, coordinate, and review information for inclusion in the Bulletin and the digital Rheology Digest:
   a. Society Secretary
   b. Society Webmaster
   c. Society Media Coordinator
   d. Student member
   e. Industry representative
   f. JoR Editor or Associate Editor
   g. members-at-large as desired

Furthermore, a fruitful discussion ensued about the opportunities for coordination of the Bulletin (member only), digital Rheology Digest (members plus rheology community more broadly), JoR, the SoR website, social media, etc… This included enlisting social media to help report on the SoR annual meeting, having the meeting chairs provide meeting reports for the Bulletin, and numerous additional opportunities that having a diverse and inclusive editorial board will bring to enrich Society communications with members and rheologists more broadly. We are very grateful that the Society considers the Bulletin and Society communications of sufficient importance to merit financial support, and this committee sees significant value in partnering volunteers under the guidance of paid employees of the Society and designates to provide Society communications commensurate with 21st century best practices.

The scope of the position could be modified, whereby "Bulletin Editor" may be better titled "Communications Coordinator" or some combination of these two.

The Digest may have content such as:

- Secretary announcements, including meetings and deadlines, nominations, etc…
- JOR feature
- Careers corner
- Advertisements

Furthermore, it is proposed to advertise broadly for the editor.

Minutes prepared by Kal Migler
SOR Secretary
Last updated 11/15/2020

Treasurer's Report

By: Chris White

The Society of Rheology (SOR) is currently in sound financial condition. There are concerns going forward, but these have been mitigated in the short term. For the year 2020, the SOR ran a surplus of $149k. This increase in net revenue is largely attributed to a decrease in the cost of producing the Journal of Rheology (JOR).

The financial direction of the SOR/JOR is an important topic for ongoing discussion, because while the Society has substantial reserves, it also faces risks with regard to meeting liability and changes in the scholarly publishing environment. This critical discussion will require significant conversation about the financial goals of the Society of Rheology and how they support the mission of the society more broadly. Currently, the treasurer's responsibility is to run a cost neutral annual budget while anticipating and insuring against potential financial shocks to the Society of Rheology.

A summary of the major components of the 2020 budget is listed below.

SOR has significant financial reserves, a strong brand, and a dedicated membership base. The accompanying charts document expenditures and revenues for the specific time periods in the society's history. In 2020, even though there was no annual meeting, there were several expenses related to the 2019 Raleigh, NC meeting. A more extensive discussion follows. The dues revenue was in-line with previous years. The venture fund is listed above, and it is not counted as revenue, but as an asset. The net revenue for SOR in 2020 is predominately due to the subsidy created by the combination of constant revenue and the decreased production cost for the Journal of Rheology.

We are a society with financial reserves that requires more extensive oversight and management. The Executive Committee has recognized this transition and taken three definitive steps: the establishment of a regular formal audit, financial advisement committees, and a partnership for publishing the JOR.

The society greatly appreciates the contributions from the three members of the 2020 Audit Committee: **Monty Shaw, Bamin Khomami, and Rekha Rao**. The Audit Committee has already met, examined the books, reported to the executive committee and delivered recommendations on the accounting practices for the Society at the 2020 annual meeting. These recommendations have been implemented.

The society also appreciates the contributions from the three members of the 2020 Financial Advisement Committee: **Michael Solomon Wesley Burghardt, and John Brady**. This committee is charged with developing specific recommendations for investments based on the directions given by the Executive Committee. The 2021 incarnation of this committee, Wes, John and new member Lisa Biswal, will present its findings at the spring Executive Committee meeting.

The third major change started in 2019 and continuing into 2020, was the five-year partnership with the American Institute of Physics Publishing (AIPP) for the Journal of Rheology. While this arrangement has several implications, here we will address the impact on the treasury. The partnership will guarantee revenue of $100k/yr. to the Society of Rheology. Any net revenue greater than the $100k minus the expenses, will be split with AIPP in a 50-50 arrangement.

TABLE 1. Society of Rheology, January- December 2020.

Revenue		**Expense**	
Net Revenue (no meeting.*)	$(12,566)	AIP expenses	$ 34,064
Dues	$ 81,552	Awards	$ 22,742
Journal of Rheology	$ 239,813	Journal of Rheology	$ 44,707
Venture fund	$ 27,000	Executive Committee	$ 0
Interest Revenue	$ 10,813	Student Travel	$ 31,000
Total Revenue	**$ 333,104**	**Total Expenditures**	$ 183,673
		Net Revenue^	**$ 149,431**

*This is from 2019 meeting, see detail below.

^ NR is accurate, not all accounts are represented.

Journal of Rheology

Prior to 2004, SOR subsidized the publication of the JOR. In Figure 1, from 1998-2004 the net revenue from the JOR was *de minimis*. Figure 3 and Figure 4 shows the significant expenses relative to revenue for producing and distributing the JOR were the underlying cause. In 2005, the publication of JOR was moved to AIPP from a commercial publisher. This resulted in decreasing cost to produce JOR. With stable revenue and decreased cost, net revenue was produced and transferred to SOR. From 2005 to 2018, the JOR has positive revenue that varied from ~$50k/yr. to ~$100k/yr. There were two years, 2011 and 2012, with one-time revenue jumps, but the underlying finances of JOR remained stable within this range. Starting in 2013, the net revenue from JOR began to decrease (declining subscription revenue, increased production costs) with 2014-2016 consistently closer to $50k than $100k. Beginning in 2017, the SOR began deeper partnerships with AIPP resulting in increased revenue through consortium marketing and decreased cost of producing JOR

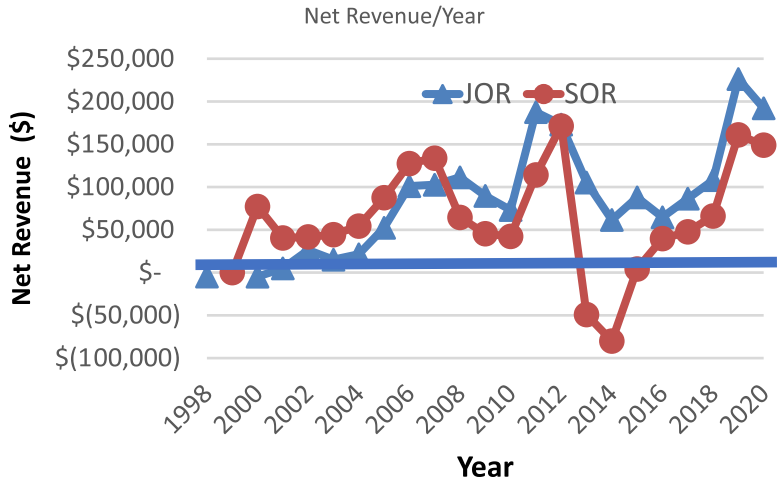


FIGURE 1. The annual Net Revenue from the Society of Rheology and the Journal of Rheology.

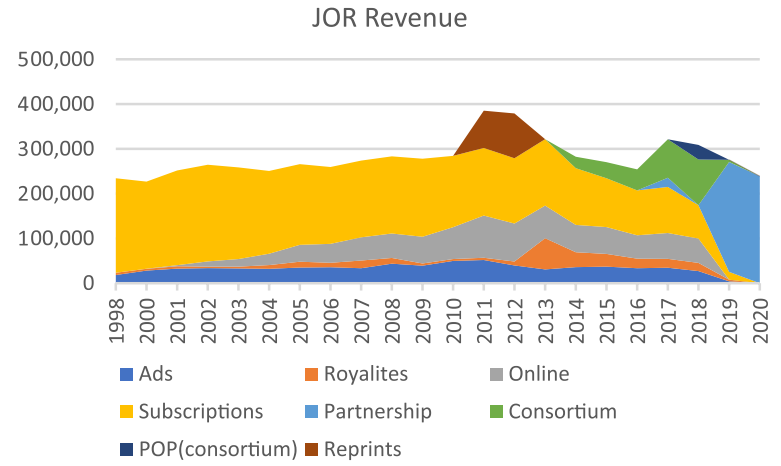


FIGURE 2. Journal of Rheology Revenue from 1998-2020.

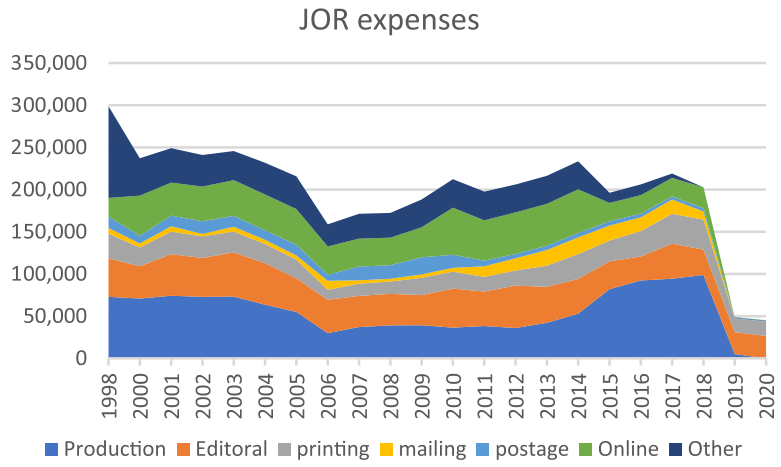


FIGURE 3. Journal of Rheology Expenses from 1998-2020.

resulting in increased JOR net revenue. As this data suggests, JOR is not fixed, or a guaranteed source of revenue over time (in the short term, there is a guarantee for the next three years). There are several unresolved threats to this economic model. The largest of these is Open Access. Open Access may result in libraries no longer being willing to pay for a full or even partial subscription to JOR. As our history demonstrates, even small changes in the revenue, library subscriptions, or cost of production of JOR will significantly affect the net revenue.

Society of Rheology

As shown in Figure 3, the revenue for the SOR outside of the journal is mainly from two sources: membership dues and interest on reserves. The dues revenue has remained flat or decreased from 1998-2016. A modest dues increase was implanted in 2016, resulting in an annual increase in revenue from ~$60k to ~$80k. The interest on the reserves, a feature of the revenue from 1998-2007 was basically eliminated as a source of revenue until a modest return in 2018. In 2020, this revenue collapsed temporarily due to a sudden drop in interest rates.

The expenses associated with running SOR have shown an unrelenting five-fold increase from 1998 to 2020. The average increase in expenses is over $7k/yr. over this period. After 2007, the SOR depends on a subsidy from JOR because SOR expenses exceed the SOR revenue. It is reasonable to assume that the expenses associated with SOR will continue to increase with no offsetting increase in revenue. Besides these historically increasing expenses, there are several significant, anticipated increases in expenses expected soon.

Society Meetings

The meetings we have grown accustomed to attending are not feasible at locations such as Chicago, Austin, even Raleigh without subsidy. Estimates for this subsidy have exceeded $100k/meeting. SOR takes on significant liability in hosting these meetings. SOR narrowly avoided paying out on the liability of $300k contract to cancel the February 2021 Austin meeting. Typically, SOR has four or five such contracts for future meeting spaces at any given time. This total exceeds $1M in contracted liability for future meetings. While the probability of losing this substantial outlay due to unforeseen

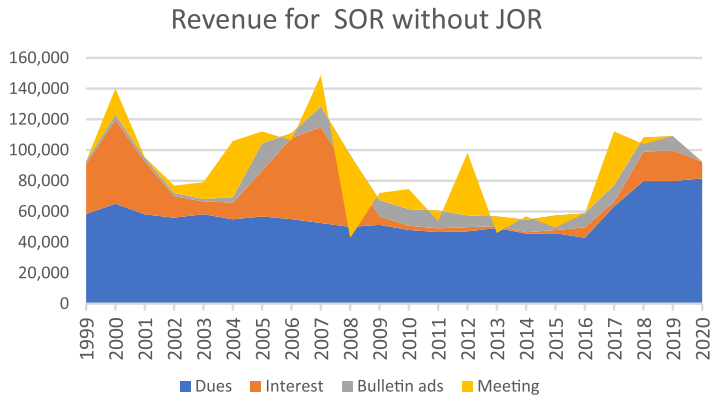


FIGURE 4. Revenue from SOR without JOR from 1999-2020.

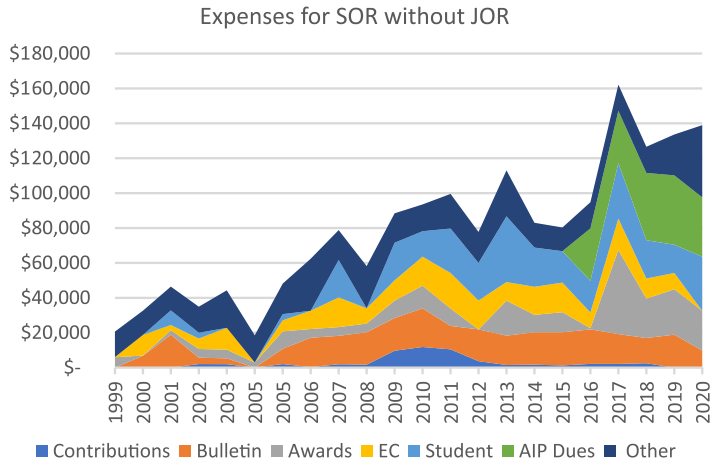


FIGURE 5. Expenses from SOR without JOR from 1999-2020; there is a 5-fold increase in expenses over this period.

TABLE 2. Revenue and Expenses for the past five years for Society of Rheology.

The Society of Rheology	2020	2019	2018	2017	2016
RECEIPTS					
Dues	$ 82,460	$ 77,890	$ 79,840	$63,935	$42,892
Interest	$ 10,831	$ 29,033	$ 19,173	$6,817	$6,812
Journal of Rheology	$ 239,813	$ 275,613	$ 308,773	$295,172	$270,858
Donations			$ 2,500		
Bulletin Advertising		part of AIPP	$ 9,265	$10,855	$9,113
Annual Meeting	0	$ (13,725)	$ (14,855)	$32,474	$ -
Short Course (net)	0	$ 10,371	$ 10,500	$10,575	$ -
TOTAL RECEIPTS	**$ 333,104**	**$ 382,536**	**$ 415,196**	**$419,828**	**$329,675**
DISBURSEMENTS	**2020**	**2019**	**2018**	**2017**	**2016**
AIP Dues Bill & Collect.	$ 34,065	$ 39,769	$ 38,547	$28,561	$25,942
Journal of Rheology	$ 47,707	$ 49,308	$ 200,622	$208,742	$200,372
Bulletin	$ 9,800	$ 18,920	$ 21,073	$17,036	$19,770
Awards	$ 22,742	$ 25,996	$ 22,572	$49,828	$3,602
Executive Cmt. Meetings	$ -	$ 9,318	$ 11,493	$18,163	$9,028
Discr. Funds.	$ 3,456	$ 2,196	$ 1,493	$3,966	$4,325
International Activities Fund	$ -	$ 2,892	$ 3,065	$2,963	$4,469
Student member travel	$ 31,000	$ 16,260	$ 22,000	$31,767	$15,097
Mis (ins, acc, ws,etc)	$ 34,903	$ 29,616	$ 28,507	$11,607	$11,870
TOTAL DISBURSEMENTS	**$ 183,673**	**$ 194,275**	**$ 349,372**	**$372,633**	**$294,475**
Net	**$ 149,431**	**$ 188,261**	**$ 65,824**	**$47,195**	**$35,200**

circumstances is small, 2020 has demonstrated that it is a possible outcome. This potential liability is covered only by our reserves.

Professional Services

SOR is the smallest of the AIP societies. We are the only society that has no professional staff. Everything SOR does is based on the efforts of volunteers. THANK YOU! Increasingly, as these responsibilities grow, these volunteer efforts are being replaced with subsidized positions. For example, JOR requires two subsidized editors, the bulletin editor has transitioned to a subsidized communications coordinator. Albert has done a great job with our website for many years. Eventually, the demands on the website will outstrip even Albert's ability to meet our collective expectations. Effective websites require significant investment, which would increase the society's annual expenses. Even the sharing or hiring of a single paid full-time staff for SOR could wipe out any projected annual net surplus. There are always significant unanticipated expenses, for example, in 2020 there was an unanticipated $18k in legal fees to ensure compliance with data privacy laws in Europe.

Reserves

Where did the SOR reserves come from? The reserves shown in the balance sheet are a result of planned net revenue from the SOR from 1929-2004 and then net revenue from JOR from 2005 to 2021. By 1997, SOR had accumulated $777k in reserves by ensuring revenue (primarily dues) greater than expenses. The reserves, as currently envisioned, anticipate a one-year shock to the system with a return to previous condition. For example, having to pay $300k to cancel a single meeting (such as in 2001 in Bethesda or 2020 in Austin) completely depletes the meeting reserve. This model does not anticipate long-term changes in the revenue and expense model for JOR. Our history has shown that the current profitability of JOR is not fixed. Our performance also shows that the expenses associated with running SOR will continue to increase and therefore rely more and more on the uncertain subsidy provided by JOR.

This reserve allows time for future executive committees to respond to these one-time or systemic changes. The reserves provide future executive committees the opportunity and flexibility

TABLE 3. Sources of Revenue for Journal of Rheology. Notice the shift in revenue sources in 2019 and 2020.

Journal of Rheology	*2020*	2019	*2018*	2017	2016
Sales		$ 4,313	$ 27,085	33,000	$33,603
Royalties		$ 3,709	$ 18,285	22,000	$21,340
Single-Copy			$ 2,863		$3,342
Consortium Access Fees		$ 5,000	$ 54,432	53,169	$52,081
Consortium Subscription			$ 94,025	86,663	$45,734
JOROL Income					$ -
Subscriptions		$ 17,591	$112,083	100,340	$99,385
AIPP	$ 100,000	$ 100,000			
sharing	$ 139,000	$ 145,000			
Revenue	**$ 239,000**	**$ 275,613**	**$308,773**	**$295,172**	**$255,485**

TABLE 4. Journal of Rheology expenses and net revenue. 2019,2020 show significant decrease in expenses associated with producing the journal.

	2020	2019	2018	2017	2016
Revenue	**$ 239,813**	**$ 275,613**	**$ 308,773**	**$295,172**	**$255,485**
Fixed cost		$ 31,854	$ 126,818	$122,492	$114,516
Print		$ 17,454	$ 49,071	$64,000	$62,121
Online			$ 24,772	$22,250	$22,166
Total Expenses	**$ 47,707**	**$ 49,308**	**$ 200,661**	**$208,742**	**$198,803**
NET	**$ 192,106**	**$ 226,305**	**$ 108,112**	**$86,430**	**$56,682**

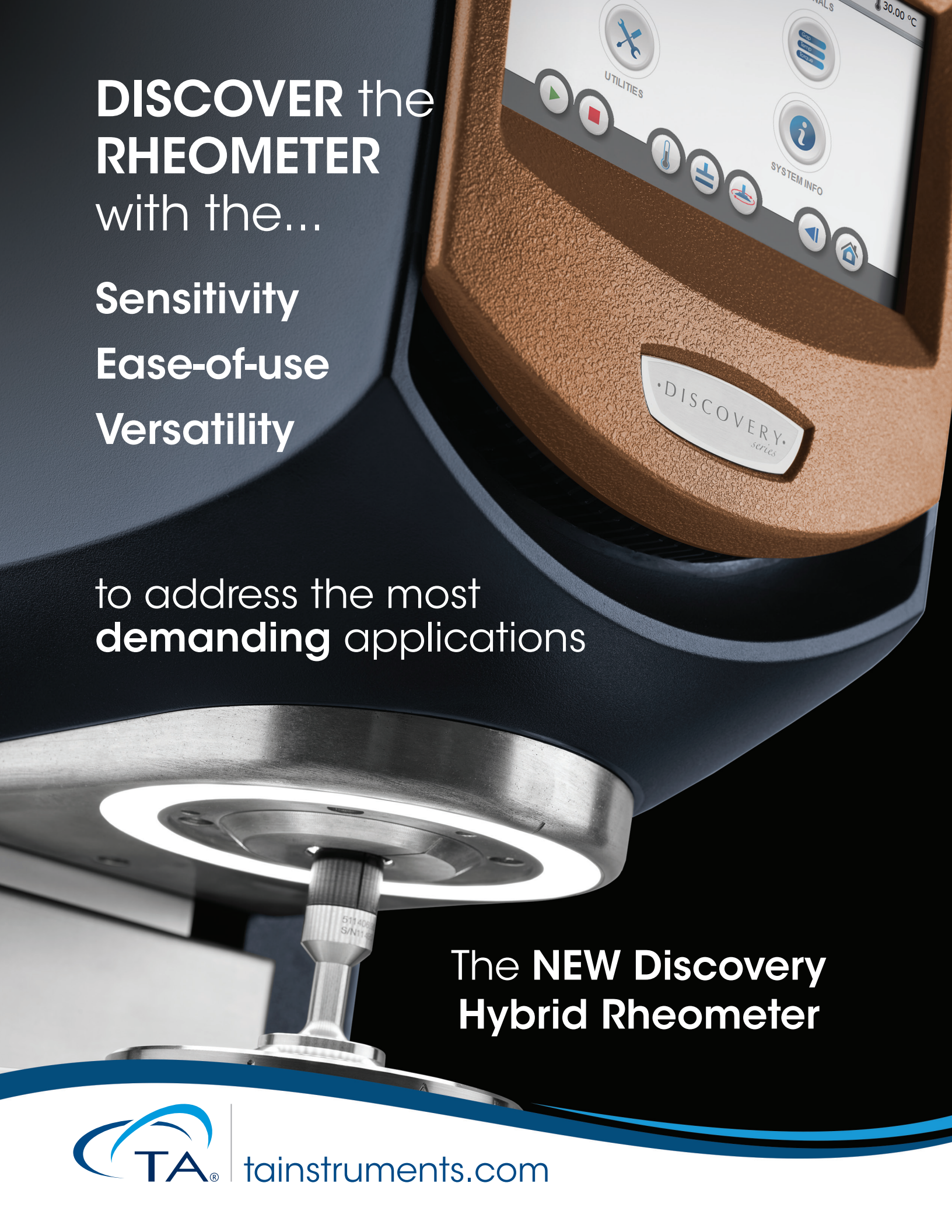
TABLE 5. Balance sheet for SOR from 2016-2021.

The Society of Rheology, Inc. Balance Sheet	**2020**	**2019**	**2018**	**2017**	**2016**
Assets					
Cash in checking account(s)	$ 47,741	$ 46,727	$ 27,774	$ 7,096.35	$ 45,027
Balance in AIP account	$ 449,440	$ 354,665	$ 862,081	$ 850,906	$ 1,807,110
Schwab (Reserve1)	$ 947,471	$ 942,513	$ 1,018,793	$ 1,003,872	
Schwab (Reserve2)	$ 608,604	$ 602,731			
Accounts Receivable	$ 141,564	$ 157,426	$ 1,197		$ 5,000
Prepaid Expense	$ (8,500)	$ 36	$ 36	$ 36.00	$ 10,269
Total Assets	**$ 2,187,376**	**$ 2,104,098**	**$ 1,909,880**	**$ 1,861,911**	**$ 1,867,406**
Liabilities and Net Assets					
Liabilities					
Deferred revenue	$ 32,245	$ 126,398	$ 122,190	$ 140,325	$ 193,550
Venture Capital Fund	$ 27,000				
Total Liabilities	**$ 59,245**	$ 126,398	$ 122,190	$ 140,325	$ 193,550
Net Assets					
Publication reserve	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000
Student travel grant reserve	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
Annual Meeting reserve	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
Operating reserve	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000
Unrestricted	$ 1,048,700	$ 859,439	$ 791,586	$ 743,857	743,856
Net Revenue	$ 149,431	$ 188,261	$ 66,105	$ 47,729	$ 39,743
Total Net Assets	$ 2,128,131	$ 1,977,700	$ 1,787,690	$ 1,721,586	$ 1,713,599
Total liabilities and net assets	**$ 2,187,376**	**$ 2,104,098**	**$ 1,909,880**	**$ 1,861,910**	**$ 1,907,149**

to consider new innovative initiatives or just to keep the society running in times of crisis. Because of our reserves, we were able to pay deposits for future Bangor and Chicago meetings and support student participation in the ICR while faced with the possibility of a large penalty for breaking contracts for Austin, instead of having to make tough choices due to limited budget.

The reserves also offer the opportunity to buffer the uncertainly associated with the subsidy required by JOR revenue to keep SOR running. Establishing interest revenue and using a portion of that interest income to fund SOR operations is a path that has been used in the past (pre 2007). To increase the return on investment requires exposure to downside risk to the principal. The finance committee is charged with making recommendations to the executive committee around this balance between risk to principal and return on investment. The reserves function like that of an endowment for SOR operations to offset future expenses and financial shocks.

How much reserves should SOR maintain? As our past has shown, the current net revenue from JOR is not assured, yet the expense of running SOR continue to increase. As the revenue from SOR remains flat, any financial shocks or increased future expenses must be paid from these reserves. There are significant future expenses that will require funds. In this uncertain future, the current temporary surplus from JOR should be considered a safeguard against future, unexpected expenses, liability exposure. The presence of the reserves allow SOR and the executive committee to focus on our mission, to expand the knowledge and practice of rheology through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what rheology is, and how it impacts humanity and the world.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