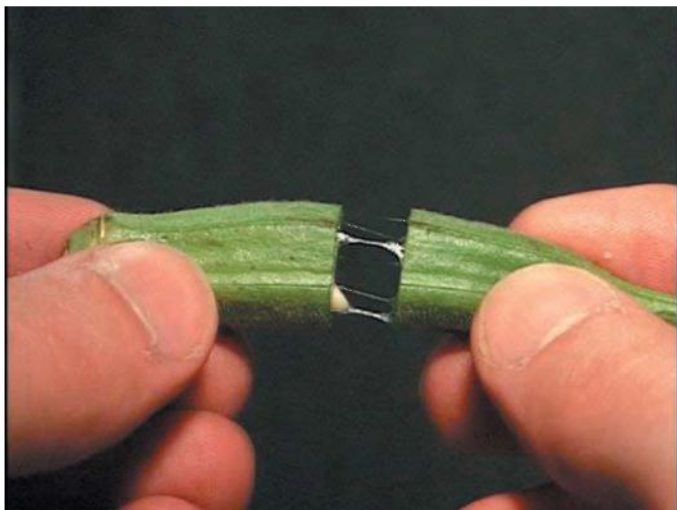

THE BRITISH SOCIETY OF RHEOLOGY

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THE BRITISH SOCIETY OF RHEOLOGY

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THE BRITISH SOCIETY OF RHEOLOGY



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CONTENTS

Editorial	58
BSR News	
President's Commentary: Professor Macolm Mackley	59
BSR 2006 Annual Winter Meeting, The University of Manchester	60
BSR Annual Award Citation 2006, Oliver Harlen	65
Commentary on the 318 th Council Meeting: The University of Reading	67
Commentary on the 319 th Council Meeting: University of Manchester	69
Notice of the 66 th BSR Annual General Meeting	71
Karl Weissenberg - The 80th Birthday Celebration Essays:	
The physical meaning of Weissenberg's hypothesis with regard to the second normal-stress difference	72
Rheology Reviews 2006	84
Conference Announcements	85
Non-Newtonian Club News	87
Aims of the Society	89
Industry News	90
Conference & Courses Dairy	95

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EDITORIAL

SUBMISSIONS TO THE BULLETIN

Submissions to the Bulletin may be made by any practical means – post, email, disk, fax, pigeon, donkey, guide dog, *et cetera* but electronically is preferred (saves typing...). Most packages supported (Word, TeX, LaTeX, WordPerfect, ASCII, RTF) but always provide a contact name, address, e-mail, or telephone number in case of problems.

The next copy date will be in April 2007 and, as always, all contributions are gratefully received. Late copy can sometimes be accommodated, however the facilities of the BSR and ESR web sites may also be appropriate. Please contact the Editor for details (Bogdan Dobraszczyk, b.dobraszczyk@reading.ac.uk).

COVER ILLUSTRATION

The cover illustration shows elastic fibres being formed when an Okra is broken.

We are always looking for appropriate colour or black and white pictures for the front cover of the Bulletin and Rheology Abstracts (preferably of a rheological nature!). Please contact either Bogdan Dobraszczyk (Bulletin Editor, b.dobraszczyk@reading.ac.uk) or Nick Hudson (Abstracts Editor and Publications Manager, n.e.hudson@strath.ac.uk). Contributions are always welcome!

BSR NEWS

BSR President's Commentary

Two years as BSR president has slipped past with a power law index of less than 0.1. There have been a number of key issues to address, not least the position of the BSR and the ESR. Hopefully both organisations will continue to flourish and continue to work alongside each other. The state of Rheology reflects many similarities to the relation of the UK to the EU. There are clearly benefits in a European Union and also there are benefits in retaining National identity.

It is pleasing to see that the BSR has become conference active again. It is easy to argue that there are already too many conferences; however the BSR conferences I have attended over the last two years have been very worthwhile for many different reasons.

The BSR has invested heavily on the development of the BSR web page and there is great potential for this portal as a future means of communication at several different levels and both Council members and general BSR members should now actively engage in making this a lively place.

In terms of the future, I am delighted to say that Prof Phil Banfill has agreed to be nominated by the committee as the next BSR president, also Dr Helen Wilson has agreed to be nominated as secretary. The proposed BSR committee has a good blend of experience and youth and it is exciting to see young members on the committee. Our future is of course with them.

There are many things that we did not achieve during my two year stint and the failings are probably all mine. We have a dream that hopefully will be reality in the future in that the BSR will be able to offer Rheology Reviews free to BSR members. This hopefully would add value to BSR membership and also help spread the word in relation to the excellent content of Rheology Reviews.

Wishing you all pleasant future flow curves.

Malcolm Mackley, BSR President

BSR 2006 Annual Winter Meeting

Dynamics of Biofluids and Biomaterials

Manchester Interdisciplinary Biocentre, School of Chemical Engineering and Analytical Science, The University of Manchester

11-12th December 2006

The 2006 BSR annual meeting provided an excellent opportunity to explore the frontiers of research on dynamics of biofluids and biomaterials from molecular to cellular and tissue length scales and on micro-fabrication of biomaterials.

Professor John McCarthy, Director of the Manchester Interdisciplinary Biocentre, opened the meeting describing how The University of Manchester had been successful in securing substantial funding for the Multidisciplinary Biocentre and how the centre was committed to studies across the whole spectrum of biomedical research. The Conference commenced with three presentations on blood flow. The first from Professor Gerard Nash (Birmingham) described optical experiments on the way white blood cells can adhere to vessel walls for different blood flow conditions. The second presentation by Dr Izzard correlated blood flow, blood pressure with wall artery expansion and Malcolm Mackley followed with a talk on equine blood flow where he showed that whilst rheological data was something of a nightmare, rheo-sedimentation results were systematic and worthy of analysis. Prof Brian Derby finished the morning session demonstrating that most living cells can survive the trauma of ink jet printing.

The afternoon session, entitled *Dynamics of Biomolecules*, was opened by Tom McLeish, whose talk was on *Doing Single Molecule Rheology with Biopolymers*, or “Feel the Noise”. This was a fascinating lecture on novel interpretations of AFM force data on single biopolymers. Single biopolymer molecules can be stretched in an AFM and their force traces recorded, and there has been some success in ascribing irregularities in these traces to molecular unfolding or conformational changes. Much of the force data recorded from such experiments contains a significant amount of thermal noise due to Brownian fluctuations of the molecules. McLeish and co-workers have developed a generic model of biopolymer viscoelasticity which included this Brownian fluctuation, and by analysing the AFM force-spectrum, they can obtain additional information on the conformational energy environment of biomolecules. He demonstrated that a typical signature of a simple conformational change in 2 biopolymers, dextran and cellulose, can be seen in a minimum in both the elasticity and internal friction around a characteristic force. The second lecture of the afternoon followed in a similar vein, describing *Imaging Single Biomolecules Using the Viscoelastic Properties of a Confined Liquid Film – how the recent developments in Scanning Probe Microscope made it possible*, given by Dr Massimo Antognozzi, University of Bristol. He described a

new AFM technique – Transverse Dynamic Force Microscopy (TDFM), in which the AFM tip can be vibrated by applying an oscillation waveform and measuring changes in the shear response of confined liquid films in contact with the probe. Using this technique, it is possible to measure the organization and interactions of biopolymers suspended in a liquid medium. Measurements have been made of interactions between single DNA molecules in a liquid layer, and the possibility of nano-manipulation of single DNA strands in a liquid film.

Prof Jian Lu of the University of Manchester then spoke about *Dynamic Adsorption of Proteins at Biointerfaces*. He studied the adsorption of fibrinogen and human serum albumin (HSA) onto surfaces and their subsequent surface biocompatibility, areas of importance in tissue engineering, using spectroscopic ellipsometry and neutron reflection. He described the development of a new nanocomposite material – Siloxane nanocages – which could inhibit fibrinogen and HSA adsorption onto surfaces, leading to advantages in biocompatibility of biopolymers at interfaces. This was followed by Dr Isaac Kuo-Kang Liu of Keele University, whose talk on *Nanomechanical Characterisation of Soft Biological Materials* focussed on micromanipulation of single cells and biological membranes, trapping and deforming them using optical tweezers and Confocal Reflection Interference Contrast Microscopy (CR-ICM). This technique can be used to quantify interfacial mechanical properties of cells and biological tissues, such as cell-substrate adhesion, of considerable importance in areas such as drug delivery and adsorption and tissue engineering.

The final session of the day on *Multiple Scale Modelling of Soft Matter* was opened by Prof. Kurt Kremer of the Max Planck Institute, Germany, speaking about Entangled Polymer Systems – Structure Property Relations, or the Reptation Concept Revisited. He showed how extensive computer simulations can be used to study the dynamics and rheology of entangled polymeric systems, ranging from semi-dilute solutions of flexible polymers to polymer melts. Using this approach, it is possible to quantify where and when molecular entanglements can form and contribute to bulk properties such as elasticity and viscosity. Prof. Toshihiro Kawakatsu of Tohoku University, Japan gave a talk on *Mesoscopic Modelling of Block Copolymers: Structural Phase Transition between Gyroid and Others*. Mesophases of Block Copolymerse are one of the main targets of multiple-scale modeling and nanostructuring of soft matter. Structural transitions can easily be achieved in these systems by the imposition of shear flow, temperature change or an external electrical field. The afternoon session was finished by Dr Oliver Harlen of the University of Leeds being awarded the 2006 BSR Annual Award by the BSR president, Malcolm Mackley, and followed by the 2006 BSR Annual Award Lecture, entitled *Modelling the Flow Behaviour of Polymeric Fluids* (the full text of his talk will be given in the next issue of the Bulletin).

Day two of the conference was started by the session *Micro-fabrication of Biomaterials*, opening with Prof. Mohan Edirisinghe of University College London giving an interesting talk on *Novel Electrohydrodynamic Processing and Forming*

of *Biomaterials*. This described jet-based bioprocessing using Electrohydrodynamic Atomisation, where an electrical field controls previously unstable flows to produce a near monodisperse distribution of particle sizes down to nanoscale dimensions. It is also possible to fabricate grids, meshes and scaffolds for tissue engineering applications. Dr Gerard Marx of the University of Manchester then gave a presentation on *Tissue Engineering with Electric Fields: Microfabrication of Haematopoietic Stem Cell Microniches*, where electric fields are used to control the differentiation of the stem cells which control the process of blood formation. This was followed by Dr Bogdan Dobraszczyk of the University of Reading on *Rheological and Polymer Molecular Structure-function Relationships in Gluten Polymer in Relation to Breadmaking*, describing how the Pom-Pom model had been applied to the modelling of the structure and function of the gluten biopolymer responsible for the viscoelastic properties of bread dough.

The final morning session, *Characterisation of Soft Biomaterials*, was introduced by Prof. Simon Ross-Murphy of King's College London, giving a talk on *Biopolymer Gels and Gelation – Recent Progress*. This reviewed the historical progress of work, definitions and classification of gels and their rheological properties. Dr Aline Miller of the University of Manchester presented her work on *Dynamics of Self-Assembled Peptide Structures: from fibres to hydrogels*, describing molecular self-assembly of certain amino acids into fibrillar structures. The last lecture of the morning was given by Dr Constantina Lekakou of the University of Surrey on *Biomimetic Materials for Tissue Engineered Vascular and Orthopaedic Grafts*, using gelatin and gelatin/elastin gels to form structured nanofibrils by the application of strong magnetic fields.

The final session of the conference, *Characterisation of Biofluids*, started with a talk given by Dr Jeff Odell of the University of Bristol on *Microrheology and Biofluids*. Correct rheological function in biofluids is necessary for proper functioning within the body: for example, in synovial fluid and its role in joint movement, mucin in protection against infection, and ocular mucin in protecting and lubricating the eyes (not a dry eye in the house after this!). A novel test method using micro-oscillatory extensional rheometry of biofluids using a modified cross-flow rheometer was described. Dr Mark Haw of the University of Nottingham followed with *Droplet Impact in Complex Fluids: from Blood Spatter to Jamming*, a positively blood-curdling account of the rheological and image analysis of the spatter of blood drops at crime scenes, helping forensic examinations of crimes. The post-prandial digestion process was ably assisted by Dr Jason Stokes of Unilever Corporate Research UK, who described *Viscoelastic and Lubricating Properties of Human Whole Saliva*. Saliva is important in oral processing of food and mouthfeel, and also in taste perception and digestion. Saliva is generally regarded as being highly elastic, and the surface active proteins in saliva have a large impact on its rheology. Measurement of its rheology is often performed erroneously and limited to viscosity measured at a single shear rate unrepresentative of deformation rates within the mouth.

To ensure accurate rheological measurements, it is necessary to test saliva immediately after expectoration and to apply a tin layer of surfactant solution around the rim of the test plates to minimize protein adsorption at the air-liquid interface. The extensional viscosity of saliva was measured using CABER and showed for the first time that the rheology of saliva depends greatly on the method of stimulation. Mr Chris Holland of the University of Oxford finished the conference by giving a talk on the rheology of spider silks: *Comparing the Rheology of Native Spider and Silkworm Spinning Dope*. He described how the structural protein silks have evolved independently many times to serve many functions in spiders, silkworms and beetles. Natural silk fibres outperform most industrial fibres in their strength and toughness. To date, spider silk has defied all attempts at reproducing it artificially, despite increasing insights into the molecular mechanisms behind these superior mechanical properties. Spider silk is a complex composite of several different materials with entirely different mechanical properties, relying on the extrusion process to facilitate molecular orientation and structuring.

Bogdan Dobraszczyk

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Delegates at the BSR Winter Meeting in Manchester



Jeff Odell and Xue-Feng Yuan at the Winter Meeting

BSR Annual Award Citation 2006

Oliver Harlen

It gives me great pleasure to formally announce the 2006 winner of the BSR annual award to be Dr Oliver Harlen.

Oliver Harlen's work follows on from the George Batchelor, John Hinch and John Rallison school of thinking within the Applied Mathematics Department at Cambridge and he has continued to maintain and develop their tradition of excellence and rigour in the field of polymer rheology and suspensions. Working initially under the guidance of John Rallison, Oliver pioneered analytical and numerical techniques applied to solving problems relating to polymer solutions, particularly when subject to strong extensional flows. He became a FENE constitutive equation man! He collaborated with Dr Jeff Odell of Bristol Physics on double jet extensional flow experiments and he also became interested in drop deformation.

In a key move, Oliver came north to Leeds where he has successfully collaborated with Professor Tom McLeish and helped develop Leeds as a centre of excellence for polymer rheology and complex flow. He was involved with the formulation of Flowsolve, a numerical simulation package that uses Lagrangian tracking techniques. He has continued with numerical simulations of drops and has branched out into other fields such as modelling ink jet printing, foams and instabilities.

Oliver is a very worthy winner of the award and we look forward to his lecture on matching filament stretching behaviour with numerical simulation.

Malcolm Mackley, Manchester, November 2006.



**Oliver Harlen receiving the 2006 BSR Annual Award
(Editors Note - the blurred photo was not due to my shaking
hands after the previous evening's festivities – honest!)**

Commentary on the 318th Meeting of the Council of the British Society of Rheology

**Department of Food Biosciences , The University of Reading,
26th September 2006**

The 318th meeting of Council was held on 26th September in a well-hidden Board Room in the Food Biosciences department at Reading University. After Bogdan had assiduously ferried everyone into the Board Room (and Xue-Feng had escaped from the Ring Road) we made a start soon after 12.

Our first major topic of discussion was the state of the Society's finances. This was David Binding's first Council meeting as Treasurer and he was pleased to be able to report a much smaller projected loss this year than in the last few years. This was partly attributable to Rheology Reviews and partly to the website, www.bsr.org.uk - both ventures on which Council had committed to invest in the short term, and both of which were discussed in more detail later on. We will need to eliminate the small losses we are currently running eventually, but the trend (and the balance in the bank) is pretty healthy.

Much of the rest of the meeting focused on either Rheology Reviews or the website: these two topics (and particularly the website) seem to have infinite potential for discussion!

The 2006 edition of Rheology Reviews was with the printers (a week later than planned, which seems to be a miraculously small slippage!) and the articles for the 2007 edition are in hand. In addition, Thompson Scientific have now agreed to incorporate the reviews into the ISI indexing databases (Web of Science and so on), which is a real coming-of-age for the journal. The 2005 articles have now been indexed; 2003 and 2004 remain to be done. I note (from the commentary on meeting 313, well before I joined Council) that we have committed to support Rheology Reviews for the 2006 and 2007 editions, and watch the budget with care. Although each edition so far has lost money, the trend is positive - with sponsorship coming in and costs being tightened, we expect the 2007 edition to come close to breaking even. This venture has been a huge success for the society and looks set to continue in style with Roland Keunings as editor. Much of the credit for this is due to David Binding, who has put in an enormous amount of work, above and beyond what we should be expecting of our Council members.

One area where the website has made a big impact is membership. I believe that before the recent overhaul of the site, many of our members had not paid subscriptions, some for several years, simply through lack of annual reminders and the Standing Order facility. (I speak from experience as I distinctly remember paying 3 years' subs at once, at a BSR annual meeting...). Now all the membership

records are online - as a BSR member, you can check your own status on the website, and as Council members we can check up on you too! The man who might be Phil James, who has just taken over as membership secretary from Mike Webster. Much of the handover has been a question of Mike showing Phil the knots and wrinkles of the inner workings of the web database. There were 43 new members this year, bringing the membership up to around 400, which is a very healthy size for the Society. The income from membership can largely be attributed to the web work, but of course there are still a few problems to be ironed out. We spent some time talking about how best to ensure that we don't send demands for payment - or indeed anything else - to our deceased members!

We also had a protracted discussion of the short-term future of the website: what needs changing, what can wait, and how much we are prepared to pay. Presented with four possible tasks to implement, we compromised (of course!) and over the next year or so the website will be upgraded to allow conference management, and moved onto a more stable database format (MySQL rather than Access, if anyone outside of Council cares!). There was also some discussion of supporting an in-house rheology database; time will tell on that one.

Enough of the website, we then moved on to the Non-Newtonian Club. Jason reported on a very successful meeting in summer 2006, with 31 people attending.

This year there have been four entries for the Vernon Harrison doctoral prize - which is a very happy view on the state of rheology in the UK. A judging committee was formed containing only neutral members of Council - not an easy task with four very different candidates from around the UK! The winner will be invited to speak at the BSR meeting at Lake Vyrnwy in April, and will be presented with 500 pounds, a certificate and a copy of Rheology Reviews 2006.

The final area we needed to discuss was our nomination for a successor to Malcolm Mackley as president of council. We agreed to approach Phil Banfill - straying from commentary on the meeting for a moment, I am delighted to be able to report that his response was very enthusiastic.

We'll meet again at the BSR Winter meeting: we'll look forward to the presentation from the Vernon Harrison prizewinner!

Helen Wilson

Commentary on the 319th Meeting of the BSR Council

Manchester Interdisciplinary Biocentre, University of Manchester, 12th December 2006

The 319th BSR Council Meeting took place in the impressive surroundings of the recently opened Manchester Interdisciplinary Biocentre (MIB). Some of the statistics associated with the centre, taken from the MIB website, give an idea of its scale: it cost £35m, has a floor space of 141,000 sq. ft. and can accommodate over 500 research staff. The reason we were in such splendid surroundings was that our host, Xue-Feng, had arranged for the Council Meeting to follow on from the BSR Annual Meeting, on Biorheology, which had been running over the previous two days. A report on the BSR Annual Winter Meeting can be found elsewhere in this issue of the Bulletin.

Several council members had attended the Annual Meeting and they, and new arrivals, assembled at 4pm to commence. The chair and current President, Malcolm Mackley, began by announcing that he had to leave at 6pm in order to travel to another meeting and so immediately appointed a deputy chair, anticipating that Council Meetings rarely finish in less than two hours. Jason Stokes graciously accepted this task. Council's nomination for the next President, Phil Banfill, also attended the meeting and no doubt felt a sense of déjà-vu as items that had been under discussion when he was last on Council re-surfaced.

Matters Arising touched on the question of payment of expenses for attendance at ESR Council Meetings and it was agreed that the current arrangements should continue for the foreseeable future. The chair raised the issue of the proposed amendment to the ESR Constitution concerning 'sub-groups'. This item had been discussed at the last Council Meeting, a response had been sent to Professor Manfred Wagner who, in turn, had circulated it to other European Societies. To date, there had been no response.

There were no major items concerning membership save for that of contacting members who were not up-to-date with subscription payments. It was felt that after a reasonable period had passed, and if no response to continuing requests for subscriptions was forthcoming, then such members would be assumed to have effectively resigned. The main item raised by the Hon. Secretary, Tim Phillips, was the confirmation of the 2006 Vernon Harrison Prize, which had been awarded to Joel Miller for his work on shear flow instabilities of viscoelastic fluids. The entries for this year's prize were of a very high standard and careful consideration by the adjudicating panel was required in order to determine a clear winner.

Nick Hudson reported on the production of Rheology Abstracts and commented that it would be useful to have more abstractors in the area of food/food

processing. Bogdan Dobraszczyk was pleased to note that there is currently plenty of material coming in for the Bulletin and that the next issue would be completed early in 2007.

At this point the Hon. Treasurer, David Binding, arrived after a difficult car journey across the border from Aberystwyth but, unflustered, he proceeded to disclose the current financial state of affairs of the Society. In short, two items dominate the finances, namely the production of Rheology Reviews and support for the website. David reported that the major expenditure associated with the development of the website is coming to an end, although continuing support was essential, and that the gap between costs and income from Rheology Reviews is narrowing. He considered that it was therefore reasonable to expect that, having managed a period where expenses on these two items has been relatively high, as anticipated, a more stable financial situation should now evolve. David also noted that the production of the next edition of Rheology Reviews was well under way, with several authors already in place.

The next meeting of the Non-Newtonian Club was expected to take place early in 2007 and Jason Stokes explained his plans for the way in which he would like to take this BSR activity forward. These centred on holding two, possibly three, meetings a year at venues which guaranteed a good local audience, for example at a university with a substantial group of research students, and which were supported financially by one or more industrial organizations. A central London location was preferred for the next meeting.

The final major item was a run through of future rheology meetings. The list looks very healthy, with several meetings scheduled to take place in 2007 and 2008. It was agreed that the BSR would support a bid to hold the 2009 ESR Conference at Cardiff.

There being no other business, and with Malcolm still present, a very productive and efficiently chaired meeting ended at 6.00pm. Those members who had to dash off to various locations around the country said their goodbyes and those staying overnight in Manchester left for a very pleasant evening meal organised by Xue-Feng.

Phil James

British Society of Rheology

Notice of the 66th BSR Annual General Meeting

The 66th Annual General Meeting of the British Society of Rheology will be held on Tuesday April 3rd 2007 at Lake Vyrnwy Hotel, Mid Wales, starting at 17.10.

The minutes of the 65th Annual General Meeting are enclosed with this notice.

Members are reminded that, under rule 7(b), the business of the meeting includes:

- (i) Election of Officers and Council members.
- (ii) Receipt of a report and accounts from Council.
- (iii) Dealing with matters raised by Council or by any other member and receiving suggestions from members for consideration by Council.

Council's nominations for Officers and Council members are as follows:

President	Prof. P. F. G. Banfill
Hon.Secretary	Dr. H. J. Wilson
Hon.Treasurer	Dr. D. M. Binding
Membership Secretary	Dr. P. W. James
Bulletin Editor	Dr. B. Dobraszczyk
Abstracts Editor	Dr. N. E. Hudson

Ordinary members of Council

Dr. D. Bell
Prof. T. N. Phillips
Dr. J. Stokes
Prof. M. F. Webster
Prof. P. Rh. Williams
Dr. X.-F. Yuan

Further nominations for Council or for any of the Offices are invited. Nominations should be sent to the Secretary or made at the meeting (rule 5(b)). Nominees must be members of the Society, must confirm in writing that they are willing to stand and must be proposed and seconded by two members of the Society. The Hon. Secretary would be pleased to receive notice of any matter that any member wishes to raise at the AGM.

Honorary Secretary:
Professor T. N. Phillips
School of Mathematics

Cardiff University
Senghennydd Road, Cardiff CF24 4AG

10th January 2007

Karl Weissenberg - The 80th Birthday Celebration Essays

Some years ago one of our members, Professor John Harris, arranged for a number of eminent scientists to write essays on various aspects of Karl Weissenberg's scientific career in honour of his 80th birthday. This was subsequently published. The executors and family of the late John Harris have asked that these essays now be made available to the rheological community as a whole, and the BSR are glad to be the agents for this. The essays are being published in forthcoming issues of the BSR Bulletin.

Karl Weissenberg was born in Vienna in 1893 and studied at the Universities of Vienna, Berlin and Jena studying mathematics as his main subject. He later became Professor of Physics in the University of Berlin and has also held a variety of Professorships at other Universities. He has made fundamental contributions in both Crystallography and Rheology during a long and active scientific career.

This volume contains a collection of contributions by a number of well known scientific authors which gives the most comprehensive account available up to the present time of the range and depth of the scientific work of Weissenberg and locates his places in the development of both Crystallography and Rheology.

The physical meaning of Weissenberg's hypothesis with regard to the second normal-stress difference

PROFESSOR DR. H. GIESEKUS

Universitat Dortmund, Bundesrepublik Deutschland

1. INTRODUCTION

Weissenberg's concept of an elastic fluid is based on the notion of recoverable strain. But in contrast to the strain of an elastic solid, this quantity is an inner variable depending on the deformation history. It may be determined - subject to some restrictions - by the creep recovery experiment or by flow birefringence. His ideas lead Weissenberg to conclude that in steady shear flow the first normal-stress difference would be positive, i.e. there would be a deviatoric tensile stress in the flow direction while the second normal-stress difference would vanish¹.

This conclusion interested quite a few people from the beginning, partly because the model of Reiner of a non-Newtonian fluid - later termed Reiner-Rivlin fluid - which was developed shortly afterwards predicted the equality of the two normal-stress differences². Approximately at the same time Fromm³, and independently a little later DeWitt⁴, rediscovered the model of Zaremba⁵, which had been developed about 40 years earlier. This model, a modification of a Maxwell fluid

obeying the principle of material frame indifference, predicted that the normal-stress differences would be of equal amount but with opposite sign.

The first experiments, designed by Roberts⁶ and Philippoff⁷ to decide between these different hypotheses, confirmed - within the limits of experimental error - the predictions of Weissenberg and rejected those of Reiner and Zaremba-Fromm-DeWitt. Subsequently performed experiments of various scientists indicated that these conclusions had to be modified. Today it seems quite certain that in solutions of polymers, the most typical representatives of elastic fluids, the second normal-stress difference does not vanish completely. However it is about ten times smaller than the first normal-stress difference and has the opposite sign, corresponding to an additional pressure in the direction of the shear gradient. The behaviour of such fluids lies between the elastic fluid of Weissenberg and that of Zaremba-Fromm-DeWitt, although much closer to the former.

The physical background of Weissenberg's hypothesis needs therefore more consideration: Is it conceivable that elastic fluids exhibit a second normal-stress difference which is small compared to the first one although it does not vanish completely? In view of this question we will outline the formulation of constitutive equations of a fluid with vanishing second normal-stress difference for all types of flow and the additional considerations needed to obtain those of more general fluids. This will then form the basis for the final interpretation of the fact that deviations from the behaviour predicted by Weissenberg do not exceed a certain limit.

2. CONSTITUTIVE EQUATIONS OF A WEISSENBERG FLUID

In formulating the constitutive equations of dumbbells and necklace particles^{8,9} it is found that the stress tensor s may be expressed as the contravariant convected derivative of a "State tensor" S

$$s = -\rho \frac{\partial S}{\partial t} = -\rho \left[\frac{dS}{dt} - S \cdot \nabla v - (\nabla v)^\dagger \cdot S \right] \quad (1)$$

Here ρ is the density, ∇v the gradient of the velocity field and the superscribed dagger means the transpose. Especially for necklace particles this tensor assumes the form

$$S = \sum_i \frac{N_i}{2B_i} < \mathbf{r}_i \mathbf{r}_i >, \quad (2)$$

where r_i is the position vector of the i -th mass-centre relative to the centre of mass of the entire particle, N_i their number per unit mass and B_i their mobility. The angular brackets denote the expectation value taken over the particle ensemble. Thus, S is a symmetric tensor having non-negative eigenvalues. It is easy to show that Eq. (1) causes the second normal-stress difference to vanish in steady viscometric flows. As has been proposed earlier⁹, those fluids will therefore be termed Weissenberg fluids.

3. WEISSENBERG FLUIDS AS ELASTIC FLUIDS

According to Eq. (3) the state tensor S describes the configuration of an elastic network.*¹ This suggests to relate these configurations to the equilibrium configuration by means of a series of deformation tensors¹⁰,

$$S = \sum_k u_k^0 C_k \quad , \quad S^0 = \sum_k u_k I. \quad (3)$$

Here C_k is the tensor transforming $\langle r_k^0 r_k^0 \rangle$ to $\langle r_k r_k \rangle$, u_k^0 denotes the kinematic viscosity of the k -th class of mass centres in the equilibrium state and S is the state tensor corresponding to this equilibrium state, which is described by an isotropic tensor.

As usual in elasticity it is appropriate to replace the deformation tensor C_k , which is the Finger measure of deformation, by Green's measure of strain

$$E_k = \frac{1}{2} (C_k - I) \quad (4)$$

since this is proportional to the change of configuration caused by the flow. Thus a series of differential equations

$$S_k + 2 \eta_k^0 \frac{\partial E_k}{\partial t} = 2 \eta_k^0 e^{(1)} \quad (5)$$

results from Eq. (3). Here $\eta_k^o = \rho e u_k^o$ denotes the dynamic viscosity and s_k the partial stresses corresponding to the k -th class of particles so that

$$\mathbf{s} = \sum_k \mathbf{s}_k \quad (6)$$

The tensor

$$\mathbf{e}^{(1)} = -\frac{1}{2} \frac{\partial \mathbf{I}}{\partial t} = \frac{1}{2} [\nabla \mathbf{v} + (\nabla \mathbf{v})^\dagger] \quad (7)$$

is the usual rate of strain tensor.

At this stage the concept of recoverable strain is readily introduced by assuming a one-to-one correspondence between the stresses s_k and the strains E_k

$$\mathbf{s}_k = \mathbf{s}_k(\mathbf{E}_k) \quad , \quad \mathbf{E}_k = \mathbf{E}_k(\mathbf{s}_k) \quad (8)$$

with $s(0) = 0$, $E(0) = 0$ (11).

This results in a decoupled system (5) of differential equations for the elastic strain tensors

$$\mathbf{s}_k(\mathbf{E}_k) + 2 \eta_k^o \frac{\partial \mathbf{E}_k}{\partial t} = 2 \eta_k^o \mathbf{e}^{(1)} \quad (9)$$

as well as for the tensors of partial stresses

$$\mathbf{s}_k + 2 \eta_k^o \frac{\partial \mathbf{E}_k(\mathbf{s}_k)}{\partial t} = 2 \eta_k^o \mathbf{e}^{(1)} \quad (10)$$

The last equation is, although nonlinear, closely related to the constitutive equation of a Maxwell fluid; the complete system is therefore analogous to a viscoelastic fluid as described by a generalized Maxwell model. For an incompressible fluid the assumption of the linear relation

$$\mathbf{S}_k = 2 \mu_k \mathbf{E}_k \quad (11)$$

reduces Eq. (10) to the constitutive equation of a so-called Walters fluid B'

$$\mathbf{s}_k + K_k \frac{\partial \mathbf{s}_k}{\partial t} = 2 \eta_k^\circ \mathbf{e}^{(1)} \quad , \quad K_k = \frac{\eta_k^\circ}{\mu_k} \quad (12)$$

an equation, which is readily integrated. The case $k=1$ describes the Maxwell-Oldroyd fluid B. In all these cases $\mathbf{s}$ denotes the deviatoric stress to which an isotropic pressure $-p\mathbf{I}$ has to be added.

Without claiming this to be the only possible interpretation one may regard Eqs. (9) and (10) as constitutive equations of an elastic fluid in the sense of Weissenberg's concept of recoverable strain. They do not describe the effects of aggregation and disruption like the entanglement and disentanglement effects in polymeric solutions; but the idea of recoverable strain seems to require the identity of the deformable structural units.

4. GENERALIZED ELASTIC FLUIDS

Disregarding those effects makes it still possible to generalize the foregoing model¹¹. One has just to recall the very special assumption that the motion of the particles of the elastic network takes place in an, at least in an average sense, isotropic medium. In more concentrated systems one has to allow for an anisotropy caused by the orientation of the network structure. Consequently, the proportionality of the force $\mathbf{k}_i$ acting on the i -th mass-centre and its velocity $\mathbf{w}_i$ relative to the surrounding medium has to have tensorial character

$$\mathbf{K}_i = \mathbf{B}_i^{-1} \cdot \mathbf{w}_i = \mathbf{w}_i \cdot \mathbf{B}_i^{-1} \quad (13)$$

where $\mathbf{B}_i$ is a symmetric tensor.



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Since B_i will be isotropic in the undeformed medium the decomposition

$$\mathbf{B}_i = B_i (\mathbf{I} + \mathbf{b}_i) \quad (14)$$

has the property that $\mathbf{b}_i$ will vanish in the limit of no flow. Eqs. (9) and (10) will therefore be unchanged in form, provided the additional term

$$\frac{1}{2} (\mathbf{b}_k \cdot \mathbf{s}_k + \mathbf{s}_k \cdot \mathbf{b}_k) \quad (15)$$

will be added to the l.h.s.. Since the $\mathbf{b}_k$ will be functions of the complete state of strain or stress, i.e. will depend on the complete set of E_k and s_k respectively, the system of equations will no longer be decoupled. It is this additional term (15) which causes the non-vanishing of the second normal-stress difference in steady viscometric flows.

5. ELASTIC FLUIDS IN SLOW FLOW

Some qualitative insight into the behaviour of the fluids defined above can already be obtained for the special case where there is only one mechanism of relaxation. This is completely analogous to the transition from the general Walters fluid B' to the Oldroyd fluid B . In this case the stress tensor is decomposed into its isotropic pressure part, a Newtonian part and a viscoelastic part

$$\mathbf{s} = -p\mathbf{I} + 2\eta_0 \mathbf{e}^{(1)} + \mathbf{S}' \quad (16)$$

where the last part obeys a relation like Eq. (10) with the additional term (15). For this case it seems reasonable to assume that the mobility term $\mathbf{b}$ depends solely on $\mathbf{s}'$. This implies that $\mathbf{b}$ commutes with $\mathbf{s}'$ and the expression (15) simply becomes $\mathbf{b}(\mathbf{s}') \cdot \mathbf{s}'$. Consequently the constitutive equation for $\mathbf{e}'$ takes the form

$$\mathbf{s}' + \mathbf{b}(\mathbf{s}') \cdot \mathbf{s}' + 2\eta' \frac{\partial \mathbf{E}(\mathbf{s}')}{\partial t} = 2\eta' \mathbf{e}^{(1)}. \quad (17)$$

Thus, the material behaviour is determined not only by η_0 and η' but also by the material functions $E(\mathbf{s}')$ and $\mathbf{b}(\mathbf{s}')$.

To get some insight into the character of this fluid we specialize to the case of slow flow. This makes it possible to develop s' in a series of kinematic tensors, c.f. (12). Due to the appearance of the contravariant convected derivative in Eq. (17) the series of the contravariant convected kinematic tensors

$$\mathbf{e}^{(n)} = -\frac{1}{2} \frac{\mathfrak{D}^n \mathbf{I}}{\mathfrak{D} t^n} \quad (18)$$

is best suited:

$$s' = 2 \eta' [\mathbf{e}^{(1)} + K^{(2)} \mathbf{e}^{(2)} + K^{(11)} \mathbf{e}^{(1)2} + \dots]. \quad (19)$$

The choice of the factor of $\mathbf{e}^{(1)}$ is done in the light of results to follow. Likewise the functions E and b are developed as power series in s'

$$\begin{aligned} E &= \varepsilon^{(1)} s' + \varepsilon^{(2)} s'^2 + \dots, \\ b &= b^{(1)} s' + b^{(2)} s'^2 + \dots. \end{aligned} \quad (20) \quad (21)$$

Strictly speaking the coefficients in Eqs. (19) to (21) should be functions of the invariants of the kinematic tensors and s' , respectively. In the last two series one should, using the Cayley-Hamilton equation, add then the coefficients $\varepsilon^{(0)}$ and $b^{(0)}$ as factors of the unit tensor, both of which, however, contain no absolute term but vanish for $s' \rightarrow 0$. For a second-order approximation the terms $\varepsilon^{(1)}$ and $b^{(1)}$ as well as $K^{(1)}$ and $K^{(11)}$ may be taken as constants.

Utilizing Eq. (19) in (20) and (21) and inserting these later two series into Eq. (17) permits comparison of like terms. The lowest order terms yield the second-order coefficients

$$K^{(2)} = -2 \eta' \varepsilon^{(1)}, \quad K^{(11)} = -2 \eta' b^{(1)}. \quad (22)$$

In principle the higher-order coefficients of the expansion (19) can be determined successively, but we will not go into detail at this point.

6. NORMAL-STRESS DIFFERENCES IN THE STEADY VISCOMETRIC FLOW

To answer the basic question we will return to the starting point of this analysis, the normal-stress behaviour in steady viscometric flows.

In general the behaviour of such flows can be described by three functions, which may be defined as follows

$$\begin{aligned} s_{11} &= -p + q^2 F(q^2), & s_{12} &= q H(q^2), \\ s_{22} &= -p - q^2 G(q^2), & s_{13} &= 0, \\ s_{33} &= -p & , & s_{23} = 0. \end{aligned} \quad (23)$$

Here the s_{ik} are the components of the stress tensor, q is the rate of shear and the indices in their natural order correspond to the direction of flow, the direction of the shear gradient and the neutral direction. Thus, the first normal stress difference is given by

$$\sigma_1 = s_{11} - s_{22} = q^2 [F(q^2) + G(q^2)] \quad (24)$$

while the second one is ^{*2}

$$\sigma_2 = s_{33} - s_{22} = q^2 G(q^2). \quad (25)$$

In a second-order approximation for slow flow the two functions $F(q^2)$ and $G(q^2)$ may be replaced by their values at $q = 0$,

$$\sigma_1^{(0)} = (F_o + G_o) q^2, \quad \sigma_2^{(0)} = G_o q^2. \quad (26)$$

It is readily verified - c.f.¹² - that these expressions and the coefficients of the last chapter are related by

$$F_o = -2 \eta' K^{(2)} + \frac{\eta'}{2} K^{(11)}, \quad G_o = -\frac{\eta'}{2} K^{(11)}. \quad (27)$$

To lowest order the normal-stress differences are thus

$$\begin{aligned}\sigma_1^{(o)} &= -2 \eta' K^{(2)} q^2 = 4 \varepsilon^{(1)} \eta'^2 q^2, \\ \sigma_2^{(o)} &= -\frac{\eta'}{2} K^{(11)} q^2 = b^{(1)} \eta'^2 q^2,\end{aligned}\tag{28}$$

and the ratio of the two differences is

$$m_o = \frac{\sigma_2^{(o)}}{\sigma_1^{(o)}} = \frac{b^{(1)}}{4 \varepsilon^{(1)}}.\tag{29}$$

Since $2 \varepsilon^{(1)}$ is the compliance of the recoverable strain the statement $m_o \ll 1$ is equivalent to the statement that in fluids under shear the effect of the elastic compliance dominates the induced anisotropy of the structure.

For highly elastic fluids the range of validity of the approximation for slow flow is usually restricted to a very narrow range of the rate of shear, and it might well be that this range is out of reach for practical purposes. Thus the question is appealing whether readily understood conclusions can be drawn from our constitutive equation independent of this approximation.

This is, indeed, the case. To this end it seems advisable to express the shear not by E but by Finger's measure of deformation C - c.f. Eq. (4) - and, correspondingly, the anisotropy of the mobility by $B = I + b$ so that the defining equation becomes

$$\beta \cdot \mathbf{s}' + \eta' \frac{\vartheta C}{\vartheta t} = 0.\tag{30}$$

We merely assume now that β and C as functions of $\mathbf{s}'$ have the same principal axes as $\mathbf{s}'$ so that the principal values $\beta_I, \beta_{II}, \beta_{III}$ and C_I, C_{II}, C_{III} correspond to the principal stresses s'_I, s'_{II}, s'_{III} . To profit from this coaxiality one has to write Eq. (30) in the components of the system of principal axes and subsequently transform back to the system introduced above. It is readily seen that the principal values with index III play no role at all so that the problem may be treated as a two-dimensional one.

For homogeneous steady flow the contravariant convective derivative of C is given by

$$\frac{\partial C}{\partial t} = - [C \cdot \Delta v + (\Delta v)^\dagger \cdot C]. \quad (31)$$

To transform this to the system of principal axes of s' one utilizes the defining equation, which in matrix notation can be formulated as follows:

$$\begin{Bmatrix} s'_I & 0 \\ 0 & s'_{II} \end{Bmatrix} = \begin{Bmatrix} \cos \varphi & \sin \varphi \\ -\sin \varphi & \cos \varphi \end{Bmatrix} \begin{Bmatrix} s'_{11} & s'_{12} \\ s'_{12} & s'_{22} \end{Bmatrix} \begin{Bmatrix} \cos \varphi & -\sin \varphi \\ \sin \varphi & \cos \varphi \end{Bmatrix} \quad (32)$$

where φ is the angle between the first principal axis and the flow direction. This transformation yields

$$\left\| \frac{\partial C}{\partial t} \right\| = -q \begin{Bmatrix} C_I \sin 2\varphi & C_{II} \cos^2 \varphi - C_I \sin^2 \varphi \\ C_{II} \cos^2 \varphi - C_I \sin^2 \varphi & -C_{II} \sin^2 \varphi \end{Bmatrix} \quad (33)$$

Inserting this in Eq. (30) gives

$$\beta_I S'_I = C_I \eta' q \sin 2\varphi, \quad \beta_{II} S'_{II} = -C_{II} \eta' q \sin 2\varphi \quad (34)$$

as well as the defining equation for the orientation of the principal axes

$$\cot^2 \varphi = C_I/C_{II} = \varepsilon^2 \text{ (say)}. \quad (35)$$

Elementary calculation and backtransformation produces the components of stress

$$\begin{aligned} s'_{11} &= 2 \frac{C_I}{\beta_I} \eta' q \frac{\varepsilon^3}{(1 + \varepsilon^2)^2} \left[1 - \frac{1}{\varepsilon^4} \frac{\beta_I}{\beta_{II}} \right], \\ s'_{22} &= 2 \frac{C_I}{\beta_I} \eta' q \frac{\varepsilon}{(1 + \varepsilon^2)^2} \left[1 - \frac{\beta_I}{\beta_{II}} \right], \\ s'_{12} &= 2 \frac{C_I}{\beta_I} \eta' q \frac{\varepsilon^2}{(1 + \varepsilon^2)^2} \left[1 - \frac{1}{\varepsilon^2} \frac{\beta_I}{\beta_{II}} \right], \end{aligned} \quad (36)$$

and consequently the following normal-stress differences and their ratio

$$\begin{aligned}\sigma_1 &= 2 \frac{C_I}{\beta_I} \eta' q \frac{(\varepsilon^2 - 1)\varepsilon}{(1 + \varepsilon^2)^2} \left[\frac{\beta_I}{\beta_{II}} + 1 \right], \\ \sigma_2 &= 2 \frac{C_I}{\beta_I} \eta' q \frac{\varepsilon}{(1 + \varepsilon^2)^2} \left[\frac{\beta_I}{\beta_{II}} - 1 \right], \\ m &= \frac{\sigma_2}{\sigma_1} = \frac{1}{\varepsilon^2 - 1} \frac{\beta_I/\beta_{II} - 1}{\beta_I/\beta_{II} + 1} = \frac{1}{C_I/C_{II} - 1} \frac{\beta_I/\beta_{II} - 1}{\beta_I/\beta_{II} + 1}.\end{aligned}\quad (37)$$

Quite generally, we find the same situation we already encountered in the approximation for slow flow, which means that we can answer the question of this topic without restriction*³ as follows: Weissenberg's hypothesis that the second normal-stress difference vanishes in steady viscometric flows of elastic fluids, is equivalent to the assumption that the anisotropy of the mobility, induced in such a flow, is negligible. The experimental results that the ratio of the second normal-stress difference and the first one is small compared to one indicates the predomination of the effect of elastic strain over this anisotropy. As can be seen from Table 1 a ratio m approx. 1/10 by a medium recoverable strain (C_I/C_{II} approx. 2) corresponds to an anisotropy ratio of β_I/β_{II} approx. 1.2, by a strong strain (C_I/C_{II} approx. 5) of β_I/β_{II} approx. 2.5 and by a very strong strain (C_I/C_{II} approx. 10) even of β_I/β_{II} approx. 8. The observation, sometimes found, that m decreases rapidly by exceeding a critical rate of shear is fathomable since the recoverable strain can increase substantially by increasing the rate of shear even though the anisotropy has already reached its final value.

φ	C_I/C_{II}	β_I/β_{II}	m
35°	2	1.2	1/11
		1.5	1/5
		2	1/3
24°	5	1.5	1/20
		2	1/12
		3	1/8
17.5°	10	3	1/18
		5	2/27
		8	1/11

Table 1. The ratio of normal-stress differences as a function of recoverable strain and anisotropy

*¹ Elasticity may be caused by elastic connections between the mass centres (c.f. in a bead-spring model) as well as by the thermal motion of the mass centres themselves.

*² The last definition refers to the experimental fact that $s_{33} > s_{22}$. In the introduction the original definition $s_{22} - s_{33}$ was used for the second normal-stress difference

*³ This result is valid - in the steady case - also if aggregation and disruption effects are included.

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RHEOLOGY REVIEWS

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The field of rheology is extremely broad and continues to grow rapidly. With applications in almost every walk of life, important work is published in a very large number of journals and other media. Although modern computer-based technology enables the location of relevant studies satisfying certain criteria, it cannot determine the importance, or indeed, the significance of the studies. For this, it is necessary to tap the knowledge and experience of the world's most prominent specialists in rheology. This publication aims to achieve this.

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INSTITUTE OF NON-NEWTONIAN FLUID MECHANICS CONFERENCE ON “WHITHER RHEOLOGY?”

Lake Vyrnwy Hotel, Mid Wales

April 2-4, 2007

Programme

The conference will commence at 12 noon on Monday April 2nd and finish at lunchtime on Wednesday, April 4th, 2007.

The theme of the Conference will be “Whither Rheology?” Each Plenary Lecture will outline the main thrusts and highlights in the field hitherto, followed by a discussion of where the field is heading (or ought to be heading) in the future. Distinguished rheologists who have already agreed to give plenary lectures include: David Boger (Melbourne, Australia), Igor Emri (Slovenia), G Fuller (Stanford, USA), A Giacomini (Madison, USA), J Hyun (Korea), Tom McLeish (Leeds), J R A Pearson (Schlumberger, Cambridge), T N Phillips (Cardiff), R I Tanner (Sydney, Australia) and M H Wagner (Berlin).

We shall attempt to cover a number of important areas of current Rheological research by inviting the plenary speakers to present 45 min. lectures on their particular expertise. This will be followed by supporting lectures on the same theme. In this connection, A Likhtman and R. Graham (both from Leeds) have already agreed to lecture. Professor Mackley (Cambridge) will deliver his BSR Presidential address at the conference.

Venue

The meeting will be held at the Lake Vyrnwy Hotel near the village of Llanwddyn in Mid Wales. The hotel is situated in a 24,000 acre country estate with magnificent views overlooking the lake and the Berwyn mountains. It offers excellent accommodation with full conference facilities.

Costs

The total cost of the meeting (with meals and accommodation from Monday lunch to Wednesday breakfast) will be £380. Participants registering before 20 February 2007 will receive a £30 discount on their registration fee. Accompanying persons sharing a room with a participant will be charged £100.

Organizers

The meeting will be organized by Dr G W Roberts and Professor K Walters FRS on behalf of the INNFM. Those wishing to present lectures should contact Professor Walters (kew@aber.ac.uk). Hotel bookings and registration matters should be addressed to Dr Roberts (g.w.roberts@bangor.ac.uk).

Participants should return this form no later than 20th February 2007. Prospective speakers should send a 200 word Abstract to Professor Walters, no later than February 1st, 2007.

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The **BSR Non-Newtonian club** held a very successful meeting on the 6th June 2006 at the **University of Nottingham**, hosted by Dr. Karen Steel in the School of Chemical, Environmental, and Mining Engineering (SChEME) and sponsored by **Unilever Corporate Research**. The day featured quality presentations on a range of topics from both inexperienced and experienced academic and industrial rheologists in a relatively informal environment. Despite the range of topics presented, there was plenty of questions and discussion.

The day began with coffee and Danish pastries, and then a series of presentations from the more experienced scientists. First off was **Professor John Mitchell** (*Food Sciences, Univ Nottingham*) who spoke on the influence of rheology on mouthfeel and taste perception. A key point arising from the talk was that the efficiency with which food mixes with saliva influences sensory perception, although it is not yet clear what rheological property of the liquid is important in predicting perception. **Dr. Bettina Wolf** (*Unilever & Univ. Nottingham*) gave a talk on the rheology of particle stabilised emulsions, and highlighted that shear-thickening occurs at elevated droplet phase volumes that is not observed for classical surfactant stabilised emulsions. **Dr Karen Steel** (*SChEME, Univ Nottingham*) followed with a presentation on the rheology of coal during pyrolysis at temperatures of 350 to 600 °C. She highlighted that coal softens to form a foam before resolidifying, which yields the final porous coke structure but can also lead to excessive pressures in coke ovens. She showed how the combination of high-temperature rheometry with ¹H NMR spectroscopy could be used to understand the morphological changes. **Dr Robert Poole** (*Mech Eng., Univ Liverpool*) presented the shear and extensional rheology of a worm-like surfactant solution. This consisted of an anionic (SDS) and amphoteric (tegobetain) surfactant that showed substantial non-Newtonian characteristics. The extensional properties were characterised using a Capillary Breakup Extensional Rheometer.

During the luncheon interval, numerous posters were displayed and there were plenty of healthy discussions, including consideration on the impact of saliva on the taste and mouthfeel of our lunch ☺.

The next session was for our more *inexperienced rheologists*, whom all gave presentations of a very high quality. **Fotis Spyropoulos** (*Chem Eng., Univ Birmingham*) discussed the rheological and microstructure of aqueous two phase biopolymer-surfactant mixtures. Varying the amount of NaCl in the phase-separating pullulan/SDS mixtures offers the advantage of obtaining pullulan-rich and SDS-rich phases, and that analysis of the rheological data together with the observed structures/images of the mixtures under different shear/composition suggests a close link between the rheology and the changes of morphology of these two-phase systems. **Anson Ma** (*Chem Eng., Univ of Cambridge*) presented the rheology of carbon nanotube suspensions that have diameters of less than 100 nm and a length of several hundred microns; these were suspended in an epoxy resin. The suspension showed an elastic response ($G' > G''$) when no pre-shear was applied, while with pre-shear, the suspension behaved as a viscous fluid ($G'' > G'$) soon after the cessation of flow and finally recovered as an elastic solid in a time scale of thousands of seconds. **Dr. Nuno Sereno** (*Food Sciences, Univ Nottingham*) discussed the physical modification of xanthan gum through thermo-mechanical extrusion. This produces a particulate xanthan material that has improved hydration and unique viscosity enhancing properties that is dependent on the electrolyte levels. Upon heating the xanthan gum reverts into a disordered coil formation similar to non-extruded xanthan gum.

Following the tea break, which included more cakes and biscuits, **Julia Telford** (Unilever Corporate Research) gave a more industry-based presentation about appropriate techniques with which to measure the rheology of structured fluids (e.g. skin creams, sauces, spreads, dressings, ice cream). She highlighted that in many cases, the use of the vane tool is essential to obtain reliable measurements, particularly for highly thixotropic samples, and that careful consideration of the appropriate test procedure is required to obtain true and accurate rheological profiles. Julia also highlighted that the use of the simple 'slump' test could become a useful tool in factory situations to determine the characteristic yield stress of food and personal care products where expensive rheometers are impractical. **Dr. Amir Fahmi** (*SChEME, Univ Nottingham*) highlighted the rheological behaviour of magneto-rheological (MR) materials that have the ability to undergo rapid changes in their viscosity on the application of an external magnetic field. The novel MR fluid consisted of nano- and micro-sized iron particles in a polymer matrix whereby the viscosity is increased by several decades upon application of the magnetic field. The final talk was by **Dr. Yuncheng Liang** on the rheological properties of nano-ceramic suspension in the presence of non-ionic surfactant. The influence of molecular weight of triblock copolymer (PEO, PPO) surfactant on the rheology and zeta-potential of yttria stabilised zirconia was presented.

The day concluded with an *award for the best presentation* from an inexperienced / 'young' rheologist. This was awarded to **Anson Ma** for the high-quality of his scientific work and presentation skills; he receives a series of 'Rheology Reviews' books.

Future BSR Non-Newtonian Club meetings are currently being planned, and if anyone would like host and/or sponsor such an event, please let Jason Stokes (Jason.stokes@unilever.com) know. Anybody wishing to present at future Non-Newtonian club meetings should also contact Jason; this includes students and other less experienced rheologists, industrial rheologists, and academics.

Jason Stokes

AIMS OF THE SOCIETY

The way liquids flow and solids deform affects all aspects of life.

Extraction and processing of crude oil, moulding of plastics, use of toothpaste, spreading of margarine, painting and the lubrication of joints in the human body are all examples of processes depending upon rheological behaviour. Rheology is defined as the science of the deformation and flow of matter.

If your work is concerned with rheology in any way, then you have much to gain by joining the British Society of Rheology - publications, conferences and access to fellow members who, while working in a different discipline or industry, may be facing similar problems to yours. The Society is non-profit making and is registered as a charity.

INDUSTRY NEWS

Anton-Paar Physica MCR501 rheometer system at ISIS

The Central Laboratory of the Research Councils (CCLRC) has recently taken delivery of a Physica MCR501 rheometer system from Anton-Paar to support its soft matter research programme at the ISIS Spallation Neutron Source (www.isis.rl.ac.uk). In addition to the standard plate-plate and cone-plate measuring geometries for benchtop rheology, the CCLRC has also acquired the C-CTD200 Mooney-Couette measuring device for rheo-SANS; the only one in the UK. This will permit the academic and industrial users of ISIS to measure the structure of samples on length scales between 1-100 nm by small-angle neutron scattering (neutron diffraction) at the same time that the rheological response is recorded. In addition, and in partnership with the new Diamond Light Source (DLS) located at the same site, the CCLRC have also taken delivery of the Physica accessories for small- and wide-angle X-ray scattering (SAXS/WAXS). The ability to simultaneously probe the structure and response of soft materials with these two complementary types of radiation is expected to significantly enhance our understanding of concentrated surfactant systems, gels, polymers and liquid crystals under non-equilibrium conditions.

New Tribology Cell for Anton Paar MCR Series

With the new Tribology Cell from Anton Paar, a rheometer can be also used as a tribometer. Converting between instruments takes around one minute. The Tribology Cell utilizes the ball on 3 plates principle and comes with special tribology software integrated into our RheoPlus package. This enables the measurement of all tribological properties and production of plots such as Stribeck Curves. The cell has many advantages over traditional tribometers since it is able to take advantage of the highly developed MCR rheometer series:

- Extremely large sliding speed range from 10^{-8} m/s to 1.41m/s.
- Extremely large frictional force range from 0.01 to 44.5 N.
- Possibility of torque control or speed control.
- Easy and accurate temperature control via Peltier device.
- Professional software for complex test procedures

Contact: Steve Goodyer, steve.goodyer@anton-paar.com

Simultaneous Particle Imaging Velocimetry with Rheometry from Anton Paar

A typical Particle Imaging Velocimetry (PIV) apparatus consists of a CCD camera, a high power laser and an optical arrangement to convert the laser output light to a 90

light sheet. The laser acts as a photographic flash for the digital camera, and the particles in the fluid scatter the light. The camera detects the scattered light. In order to measure the velocity at least two exposures are needed. The frames are split in a large number of interrogation areas from which the displacement vectors are calculated. As a result the flow field through the whole gap in a concentric cylinder geometry can be measured. Anton Paars' PIV cell incorporates a prism that sits below the outer cylinder thus directing the light to the CCD camera. Flow curves can be produced simultaneously by the rheometer and correlated with the PIV data. For more information please contact Steve Goodyer. steve.goodyer@anton-paar.com

Thermo Fisher Scientific introduces new optical RheoScope module for HAAKE MARS rheometer platform

Thermo Fisher Scientific has introduced a new optical module for its Thermo Scientific rheometer platform HAAKE MARS. The RheoScope module simultaneously records rheological properties and changes in the microscopic structure of the tested sample. By combining rheological measurements with optical analysis, microstructures can be analyzed visually to obtain more information about a sample's mechanical properties. Combined methods are ideally suited for the analysis of shear thinning, dilatancy, thixotropy, aging and emulsification. This information is invaluable to researchers to further formulation development, process optimization and processability for food, cosmetics, pharmaceuticals, petrochemicals and other applications. The compact RheoScope module is a unique combination of an optical microscope, progressive-scan CCD digital video camera and temperature control unit that can be integrated easily into the MARS rheometer platform. The Thermo Scientific rheometer can perform normal force measurements and operate in a variety of modes, e.g. CR- or CS mode in rotation and oscillation while recording microscopic properties of the sample. HAAKE RheoWin software controls not only the rheometer, but also the optical unit, i.e. the focus and position of the polarizator. Depending on the user configuration, 5, 10, 20 or 50x magnification is available. Data, video sequences and images can be viewed on-line as well as stored in various formats for later evaluation and analysis. Based on the RheoScope design, customized user configurations can be quickly adapted in the standard module.

Key features of the RheoScope module:

- Fully integrated into the Thermo Scientific rheometer platform
- Visualization of data and images via one software package
- Simultaneous rheological and optical measurements
- All measuring modes available including normal force
- Analysis of structural changes under shear
- Quantitative characterization of particle dynamics
- Customized user configurations available

For further details concerning Thermo Fisher Scientific's HAAKE MARS rheometer platform, please visit www.thermo.com/mars. Information about Thermo Fisher's full range of Thermo Scientific rheometry and viscometry products is available at www.thermo.com/mc.

Thermo Fisher Scientific Product Wins 2006 ARM Awards

Recognized as “Innovative State of the Art” and “Product of the Year” for Kynar tank

Thermo Fisher Scientific announced that its new Kynar (PVDF) tank has won 2006 “Innovative State of the Art” and “Product of the Year” awards from the Association of Rotational Molders (ARM). The process fluid reservoir tank is an integral part of Thermo Scientific’s NESLAB ThermoFlex™ recirculating chiller used to cool equipment in a variety of process industries. The tank was molded by Formed Plastics, who received the award from ARM, a worldwide trade association with members from 58 countries. Peter Gimmel, vice president of Research and Development for Thermo Fisher Scientific’s Control Technologies’ business, said, “The ThermoFlex chiller incorporates a number of design innovations, and patents are pending. We’re proud the calibre of engineering ensured that Thermo Fisher’s vision for the tank’s features and benefits could be achieved.” Unlike traditional reservoir tanks used in recirculating chillers, the ThermoFlex tank features an unusual integrated design to deliver key customer benefits, including ease of use. An integrated sight tube with level indicator allows users to monitor fluid levels instantly. An integrated funnel promotes easy, spill-proof filling, while an integrated full-flow filter ensures clean fluid to the application and is easily removable for quick cleaning. The integrated drain port enables 100% fluid removal from the tank.

The molded and machined dimensions of the Kynar tank have extremely tight tolerances. Special cooling fixtures are used to ensure dimensional repeatability. The glass sight tube requires an unusual flatness tolerance, while a deep molded pocket meets stringent wall thickness specifications.

To learn more about the ThermoFlex recirculating chiller, visit www.thermo.com/thermoflex. Information about Formed Plastics is available at www.formedplastics.com. Details about the 2006 ARM awards can be found at www.rotomolding.org/i4a/pages/Index.cfm?pageID=3615.

Thermo Fisher Scientific offers new mobile docking station to connect existing measuring adapters to the HAAKE PolyLab OS rheometer platform

Thermo Fisher Scientific has introduced a new HAAKE OS mobile docking station to enable users to integrate their existing measuring adapters into Thermo Scientific’s newest torque rheometer platform, the HAAKE PolyLab OS. With this upgrade, users can protect their established measuring procedures while upgrading their installations. In many cases, proven, high-quality mechanical components found in older measuring mixers, single-screw and conical double-screw extruders can no longer be used because of outdated hardware and software. The new

HAAKE OS docking station addresses this problem and allows users to extend the life of their equipment. A selection of mechanical drive couplings allows users to easily fit HAAKE and other measuring adapters dating back to the 80s onto the mobile docking station. The PolyLab OS rheometer platform incorporates the standardized CANopen Bus that promotes connectivity. Peripheral devices are automatically identified and graphically shown in the MS Windows-supported software. Remote supervision and service support are also made possible. Historical mixer data and graphs can be imported into the system for integrated data evaluation and immediate productivity gains. Measuring data can be called up during operation, and a variety of user levels can be set to change test parameters and measurements for specific routines. For added convenience and precision, the mobile docking station incorporates temperature control for up to four heating zones including air cooling. Thermo Fisher Scientific successfully supports a wide range of industries with its comprehensive Thermo Scientific Material Characterization solutions. Material Characterization products analyze and measure viscosity, elasticity, processability and temperature-related mechanical changes of plastics, food, cosmetics, pharmaceuticals and coatings, plus a wide variety of liquids or solids.

Detailed information is provided at www.thermo.com/mc.

Freeman launches new software for powder tester

The new release of Freeman Technology's Data Analysis software package for the company's FT4 universal powder tester delivers faster analysis with more flexible reporting options. It incorporates the latest types of test available on this multi-functional powder measurement system, and offers a redesigned and simplified user interface. Thanks to a programme of continual development, new functions and extended measurement capabilities have been added to the FT4. These include compression, permeability and shear testing; the FT4 is now regarded as a universal powder tester. The new FT4-DA (V4) software enables the comprehensive analysis of all test types and data sets, allowing them to be represented both graphically and in report form. It also incorporates a number of new tools for users that make analysis and data representation and comparison even easier. Enhanced graphics and graphing facilities allow more sophisticated results presentation and full report customisation.

Part of the instrument's system software, FT4-DA enables rapid interpretation and summary of measured data from powder samples. It is a standalone application that can be installed on any computer, allowing analysis away from the laboratory if required. Existing FT4 users can upgrade to the new release free of charge.

More details at www.freemantech.co.uk

CONFERENCE DIARY

2007	CONFERENCES & MEETINGS
2-4 April Lake Vyrnwy Wales, UK	Institute of Non-Newtonian Fluid Mechanics Conference Whither Rheology , Lake Vyrnwy Hotel, Mid-Wales, UK. Gareth Roberts, Tel. +44 (0)1248 382480/ 382686, Fax: +44 (0)1248 361429, e-mail: g.w.roberts@bangor.ac.uk
12-14 April Naples Italy	4th Annual European Rheology Conference, AERC 2007 Mrs. Francesca R. Titomanlio, aerc2007@rheology-esr.com http://www.rheology-esr.org/AERC/2007
27 Apr - 1 May Lake Garda, Italy	EUPOC 2007 - Europolymer Conference Miss Maria G. Viola, Fax +39-050-28438, Email: mgv@dccci.unipi.it http://www.dccci.unipi.it/eupoc2007/
27-31 May Salvador Brazil	23rd Annual Meeting of the Polymer Processing Society (PPS-23) "Polymers from Renewable Resources" symposia will be part of the Technical Programme. For more information on PPS-23 and abstract submission, please visit the conference website at http://www.pps-23.com .
6-10 June Rhodos Greece	XVth International Workshop on Numerical Methods for non-Newtonian Flows - IWNMNNF 2007 Evan Mitsoulis / Vlasis Mavrantzas Conference Website: http://www.complexfluids.ethz.ch/IWNMNNF2007/
13-15 June Stavanger Norway	Nordic Rheology Conference 2007 Presenters should send a one-page abstract to the editor Johanna Aho (Johanna.aho@tut.fi) by 15th of February 2007. http://www.nordicrheologysociety.org/conference/
8-12 July Krakow Poland	IXth International Conference on Frontiers of Polymers and Advanced Materials , M. Bednarz, (registration & coordination) and E. Blaz, (coordination & www service), Krakow University Of Technology, Tel: (+48) 12 628 21 19, Fax: (+48) 12 628 20 38 E-mail: 9icfpam@pk.edu.pl http://www.9icfpam.pk.edu.pl/
26-28 Sept Sendai Japan	4th International Conference on Flow Dynamics & 5th International Workshop on Complex Systems Sendai International Center Sendai, Japan. Michio Tokuyama Institute of Fluid Science, Tohoku University Sendai 980-8577, Japan. T : 81 (Japan) -22-217-5327, F: 81 (Japan) -22-217-5327 IWCS2007@athena22.ifs.tohoku.ac.jp
7-11 Oct Salt Lake City, Utah USA	79th Annual Meeting of The Society of Rheology Michael Graham, E-mail: graham@engr.wisc.edu ; Daniel Klingenberg, E-mail: klingen@engr.wisc.edu http://www.rheology.org/sor/annual_meeting

2007	COURSES
5-9 February Centre de Physique des Houches, France	Flow In "Glassy" Systems , European Rheology School, organized P. Coussot and J.L. Barrat http://lpmcn.univ-lyon1.fr/houches2007/
20-21 Mar Berlin Germany	Amherst Rheology Course (ARC2007) Synergy between Experiments and Theory in Rheology. Registration: http://rheology.tripod.com/ARCEnrollBerlin.html Email: winter@ecs.umass.edu Website: http://rheology.tripod.com/ARC.htm
19 April & 21 June Manchester & Crawley	Basic Rheology Training Course , TA Instruments. Olivia Gibson (olivia.gibson@taeurope.co.uk)
5 – 8 June Glasgow UK	Process Rheology Dr Nick Hudson, Dept P&A Chemistry, University of Strathclyde, 295 Cathedral St, Glasgow, UK. T: +44 (0) 141 5482162; F: +44 (0) 141 5484822. E: n.e.hudson@strath.ac.uk
5 – 6 June Warwickshire UK	Rheology Workshop Steve Goodyer, Anton Paar Ltd, 13, Harforde Court, John Tate Road, Hertford, SG13 7Q T: +44 (0)1992 514730; F: +44 (0)1992 514739 E: steve.goodyer@anton-paar.com



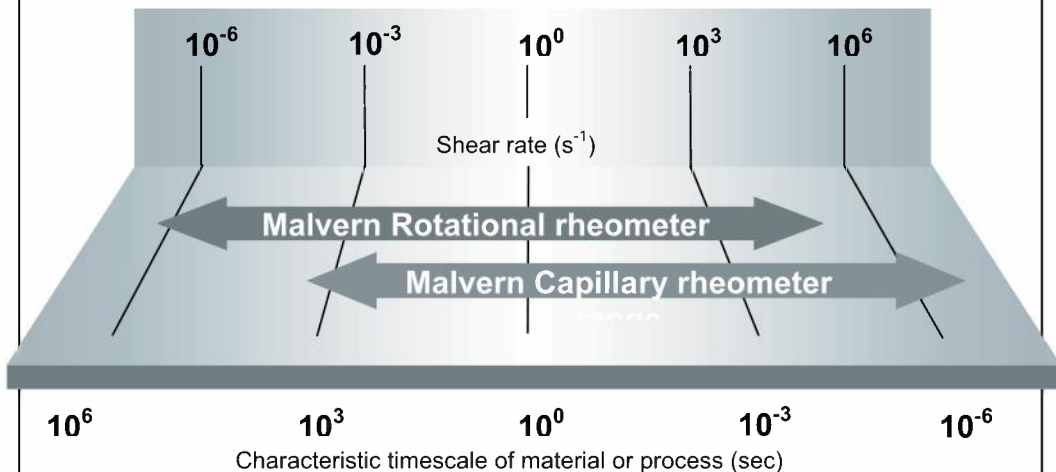
Innovations in rheological solutions



Malvern's rheological instruments have the unique ability to directly characterise material properties over 13 decades of shear rate. This means that physical material parameters can be measured, as well as their impact on process operation and end-use function.

These intelligent solutions apply to all industries where the rheological characteristics of a material determine its processability, performance and consumer acceptance.

Malvern is the only material characterisation company with specialist resources in the measurement of particle size, shape, zeta potential, molecular weight and rheology. Malvern has the understanding and expertise to advise on how these microstructural parameters influence bulk rheological properties.



Visit the Malvern Instruments website to view audio visual presentations in rheology & light scattering

www.malvern.com

$$\eta = \frac{d\tau}{d\dot{\gamma}}$$

Get the Full Picture – Combine Rheology with Microscopy

Thermo Fisher introduces the new, easy-to-use Rheoscope module for the Thermo Scientific rheometer platform HAAKE MARS. The module allows you to simultaneously record rheological properties and changes to the microscopic structures of complex fluids.

Get the full picture and visualize the interaction between the rheological and structural changes – understand how your products work.

Advantages of the combined method:

- A sophisticated rheometer combined with a powerful visualization technique.
- Ease of use: Both the rheometer and camera are controlled via the HAAKE RheoWin software. Link the structural image to flow characterization.

Visit www.thermo.com/mars to download a video of the product in action.

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