

THE BRITISH SOCIETY OF RHEOLOGY

BULLETIN



March 1995

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Hon. Editor
Mr P.C.Anderson,
32 Queensway,
Feltham,
Middlesex,
TW13 7NS



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THE BRITISH SOCIETY OF RHEOLOGY

OFFICERS AND MEMBERS OF COUNCIL. 1994/95

- President:** Prof H.A.Barnes, Unilever Research Ltd, Port Sunlight Laboratory, Quarry Road East, Bebington, Wirral, Merseyside, L63 3JW
Tel: 0151-471-3529 Fax: 0151-471-1829 E-Mail: BARNES_H@UK.CO.URPSL
- Secretary:** Dr G.J.Brownsey, Institute of Food Research, Norwich Laboratory, Norwich Research Park, Colney, Norwich, NR4 7UA
Tel: 01603-255201 Fax: 01603-507723 E-Mail: Brownsey@BBSRC.ac.uk
- Treasurer:** Mr R.E.Carter, Rheometric Scientific Ltd, Jubilee Drive, Belton Park, Loughborough, Leics, LE11 0XS
Tel: 01509-233300 Fax: 01509-234905
- Membership Secretary:** Dr N.E.Hudson, Dept of Pure & Applied Chemistry, University of Strathclyde, 295 Cathedral Street, Glasgow, G1 1XL
Tel: 0141-552-4400 Fax: 0141-552-5664 E-Mail: n.e.hudson@strath.ac.uk
- Abstracts Editor:** Dr G.H.Meeten, Schlumberger Cambridge Research Ltd, High Cross, Madingley Road, Cambridge, CB3 0EL
Tel: 01223-325204 Fax: 01223-467004
E-Mail: meeten@cambridge.scr.slb.com
- Bulletin Editor:** Mr P.C.Anderson, 32 Queensway, Feltham, Middlesex, TW13 7NS
Tel: 0181-890-6586
- Ordinary Members:** Prof P.F.G.Banfill, Dept of Building Engineering & Surveying, Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS
Tel: 0131-449-5111 Fax: 0131-451-3161
- Dr R.Burley, Dept of Mechanical & Chemical Engineering, Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS
Tel: 0131-449-5111 Fax: 0131-451-3129
- Prof A.R.Davies, Dept of Mathematics, University of Wales, Aberystwyth, Dyfed, SY23 3BZ
Tel: 01970-622755 Fax: 01970-622777 E-Mail: ard@aber.ac.uk
- Mr P.D.Doody, National Starch & Chemical Ltd, Galvin Road, Slough, Berkshire, SL1 4DF
Tel: 01753-533494 Fax: 01753-577704 E-Mail: paul.doody@nssgb.ac.uk
- Prof T. McLeish, IRC in Polymer Science & Technology, University of Leeds, Leeds, W. Yorkshire, LS2 9JT
Tel: 01132-333845 Fax: 01132-333846
E-Mail: PHY6TCBM@PHYS-IRC.NOVELL.LEEDS
- Mrs C.A.Moules, Camtel Sciences, 5 Carrington House, 37 Upper King Street, Herts, SG8 9AZ
Tel: 01763-244280 Fax: 01763-244298

EDITORIAL

This issue of our Bulletin is a bumper issue largely due to the 13 page article on the activities of the Highly Filled Materials Institute at the Stevens Institute of Technology in Hoboken New Jersey. Our thanks to Professor Kalyon who supplied this article at Professor Barnes' request to form a part of our occasional series on the research at various Rheological centres of expertise. As a part of this objective there is also a brief description of the objectives and activities of the Institute of Non-Newtonian Fluid Mechanics at the University of Wales. We would always be pleased to hear of the work being undertaken at other centres.

Following on the personal profiles of two new members on Council in the last issue, two further new members have been persuaded to write personal profiles, by way of introducing themselves to our members.

On the front of liaising with our European colleagues, I have had correspondence from a number of Societies, for which I am very grateful. From this correspondence and the attached lists of their current committees, I have extracted the names of their Presidents and Secretaries. I also report elsewhere in this issue on a number of forthcoming joint meetings. The Belgian and Dutch Societies and the Austrian, German and Swiss Societies both have joint meetings in May and the French and British Societies meet in September. There is also a report in this issue of the latest in a series of meetings in France on the current progress in a E.U. sponsored joint project on the rheological behaviour of polymer solutions. This report was written by a student who was given a grant by the BSR to help him attend this meeting. We do like to persuade students, whom we help to attend meetings, to work for their supper by producing such reports.

I hope that you will both read the article by Gerry Meeten, our Editor of the Rheology Abstracts, and take the trouble to reply to him with your ideas on how we can best continue to provide a service to our members on the current awareness front. Your Council is very concerned about the problems faced by paper journals.

The copy date for the next issue is June 30th, 1995, but please, the earlier the better!

BSR Bulletin Vol 38/1 - Erratum

Because of printing errors, the article starting on page 12 should be read in the order pp12-18, 25, 23, 24, 19.

COMMENTARY: 280th BSR COUNCIL MEETING

Battling gallantly through blizzard conditions in Yorkshire, your Council gathered at the IRC in Polymer Science & Technology at the University of Leeds for the 280th Council Meeting of the BSR. Although the meeting was due to start at 11 o'clock, the non-appearance of our President and other Council Members meant that the start was postponed for half an hour. It had already been agreed at the previous meeting that, in the absence of the President, Phil Banfill would act as our Chairman, however he was also delayed and so Tom McLeish kindly took us on a guided tour of the IRC. When the Meeting finally started (with Secretary Geoff in the chair), apologies for absence were received from Roy and Carole. In the time-honoured tradition of "he's not done a Commentary before" I was completely and utterly democratically told it was my turn for the commentary and so here it is. The minutes of the last meeting were read and agreed (although the spell checker on Geoff's word-processor kept on insisting that the conference dairy in the Bulletin was the ideal place to list events for the coming year!).

The reports from the Officers of the Council were presented. Our President hopes to increase the membership of our Society to over 700 (which incidentally only represents less than one third of each our current members encouraging one colleague to join us...). He also discussed the European Society of Rheology - but more of that below! Roy unfortunately couldn't join us once again but sent us copies of the accounts. He seems to be phenomenally busy and spends most of his time commuting between Epsom and Loughborough (*via* just about every other place around the World!). Nick brought along membership applications from four more people to join us (welcome!) and a list of about a dozen poor souls who must leave us under the famous "Rule 4(d)". An updated membership application form was proposed and will be available soon (remember, less than a third...). Peter requested more articles from EVERYONE (Members and Council) and profiles of those remaining new members of the Council who slipped through the net last time...oops! An article received from one of our American members was also agreed for publication. Gerry deferred discussion about *Rheology Abstracts* until our invited guest had spoken (see below).

The two major issues at this meeting followed on from the previous gathering of the Council. One of the most keenly discussed items at the last meeting was the issue of a future European Society of Rheology and, given the information that the Council had at the time, it was very hard for us to justify the extra overheads that, at the time, it was thought the European Society would incur on the member societies. The President sought further clarification and, after he had battled over the Pennines to join us, was able to give a few more details. A final decision has yet to be taken over the European Society and the President is currently discussing further issues. However the Council is now fully committed to ensuring that, as the oldest and largest rheological society in Europe, the BSR will help to shape and guide a body such as this for the best interests of all European rheologists. At least we didn't have a "Euro-sceptic/Euro-phobic" divide amongst Council, unlike certain institutions we could mention... John Major take note!

Also at the last meeting it was decided to invite a representative of Elsevier Science (the publishers of *Rheology Abstracts*) to discuss the current situation and future prospects of our flagship publication. Keith Lambert (Senior Publishing Editor) kindly agreed to join us here in Leeds. The demand for paper-based abstracting journals appears to be falling as more and more electronic databases come on stream and RA sales (outside the BSR) have dropped by 50% since 1986, the trend steepening (it would appear) since 1992 where we were losing approximately 10% of external circulation *per annum*. This compares with an overall decline in paper-based so-called "primary" journals of 3-6% *per annum*. Elsevier believe that RA could be better served being published by one of their smaller sister companies (who currently publish other abstracts), however a number of other initiatives were considered including a move to electronic publication or publication on computer disk. This is not an issue to be lightly considered however as it was pointed out that a large number of our members may not have access to either on-line databases or, indeed, computers. In response to a request from Council, Gerry kindly volunteered his services to Chair a Council sub-committee to investigate all the options. It is important that Council receives feedback from the Members on this issue!

As the weak sun started to sink into the melting snow (for by now the weather had improved somewhat) so Council departed back to the four corners of the country from which they came (although there definitely seems to be a northern/Scottish bias!) until the next meeting, hoping that the weather will be a little better.

Paul Doody

PROFILES OF NEW COUNCIL MEMBERS

Professor T.C.B.McLeish

Tom McLeish was introduced to polymer rheology at Courtaulds Research in 1980 where he spent a year as a sponsored student before doing a Physics Degree at Cambridge University. Unable to leave these fascinating things alone, and egged on by the discovery that the UK's principle polymer group was right on his doorstep in the form of Professor Sir Sam Edwards' team at the Cavendish Laboratory, he and they both persuaded Courtaulds to extend the arrangements to a CASE studentship looking at the consequences of the Doi-Edwards tube model for polymer melts and polymer flow instabilities.

It was during a subsequent two year postdoc, funded by ICI and still at the Cavendish Laboratory, that he developed his interest in the consequences of long chain branching for dynamics of polymer melts and in the wider class of polymer-like complex fluids such as surfactant solutions and colloidal suspensions under electric fields.

In 1989 there came a lucky break in the form of an advertisement for a Lectureship at the University of Sheffield, seeking somebody who would be able to initiate a new research theme - polymer physics was mentioned as an example - but at the same time able to teach Astronomy! Without actually seeing his name in the advertisement, Tom got excited by this as he had been stargazing on as many clear nights as he could make since the age of 10 and is still convinced that it was his O-level in Astronomy that made all the difference with the Appointment Committee! He was at Sheffield for 4 years, building up a research group in the area of polymeric and complex fluids and was involved in the founding of Sheffield University's Centre in Polymer Science and Technology, as well as getting interested in ERASMUS European Exchange Programmes for Physics students.

In 1993, he was appointed to the Chair in Polymer Physics at the university of Leeds and joined the already substantial polymer physics group there and the Interdisciplinary Research Centre in Polymer Science and Technology. Current research themes continue to include long chain branching, dynamics in polymer blends, electrorheological fluids, surfactant cubic phases and molecular mechanisms of crazing.

Regular attenders of British Society of Rheology conferences will be aware of an occasional nickname of "Hornblower". On the family front, he can now report (on 29.3.95) both a daughter age 2 years and a son age 3 days!, whose Mum, Julie is doing very well. (Congratulations - Ed.)

Paul Doody, Council Mender

Originally from Leicester, I am a graduate in Materials Technology from Coventry (Lanchester) Polytechnic where I studied from 1985 to 1989. After a brief spell earning my living as a lorry driver around Greater London, I settled into gainful employment with National Starch & Chemical, part of the Unilever group. Joining as a technologist in the Adhesives Division, I was initially responsible for developing the hot melt adhesives that hold labels onto bottles of fizzy drinks and cans of baked beans, and later for adhesives that stick cartons together - a job in which rheology figured more than might first appear. Since then my job has changed slightly and I'm now responsible for coordinating the development of new raw materials for National Starch on a European basis - a job where rheological techniques are a vital tool.

Hot Melt Adhesives are complex blends of thermoplastic polymers, hydrocarbon or natural tackifying resins, oils, and occasionally waxes, and it was in trying to optimise and explore the various combinations that brought to life the concepts that I learnt about the polymer rheology studied at college. Relishing the further challenge, I registered for a part-time Ph.D (again at Coventry - although by this time it was now a University) in 1992 studying the Rheology of Hot Melt Adhesives. I was extremely honoured to be awarded the Scott-Blair Scholarship by the BSR for 1993/1995 in support of this work.

I'm married with no children. If asked to list my hobbies I normally start with "Ph.D" although I am a keen traveller, and a voracious reader. In a previous existence I also played the tuba - so continuing the (dodgy?) tradition of musical Council members!

Now that I am a member of Council I feel glad that I am in a position to be able to contribute something back to the Society. I hope I can carry on the honourable traditions of our "Club". As an industrial member whose job involves rheology (rather than being a full-time rheologist) I believe that I can contribute a different viewpoint and I look forward to hearing any comments that any of you may have.

Paul Doody

RHEOLOGY ABSTRACTS - DISCUSSION PAPER

Rheology Abstracts (RA) are received by all Members of the BSR, and I thought it of interest to describe what is done by the Abstractors, Typist/Word-Processor, Publisher, and by myself as your Hon. Editor.

The RA is simple as a concept and a product, but there are activities in its production which are hidden to the reader. These I describe below, together with some Editorial problems, and points which may stimulate discussion in the Bulletin by the BSR members.

Abstractors, who are named in the frontispiece of RA, will see an abstract which appears to be of interest, photocopy it, and send it to me. Without the voluntary devotion of the Abstractors, there would be no RA. My task as Hon. Editor is to collect a sufficiently large number of abstracts, typically 200-250 per issue, and put them into order under the heads which you see on the outer front page of the RA. The source journals presently number about 40-50, and they too are listed in the frontispiece. Abstracts are of course more likely to come from journals such as *J.Rheology*, or *Rheologica Acta*. It becomes less probable for journals whose main business is not rheology. In the journals list however, the latter do however outnumber the former, proving the broad and pervasive nature of our subject, a matter to which I will return. Having ordered the abstracts by topic, they are word-processed, indexed, and sent to the Publisher who adds the cover and any extra material, and arranges the printing. As heirs to Caxton or Gutenberg, publishers appear to be civil and persistently optimistic characters. Keith Lambert, and his team at Elsevier who receive the RA as camera-ready copy, are no exception.

Each abstract comes as a photocopy of a journal page, and so bears the style and format of the journal of its origin. Since I took office as Hon. Ed., this confused range of material has been reduced to the uniform RA style by typist and word-processor Rachel Lindo, who also reads the material and seeks out errors and inconsistencies; usually mine.

So far all simple enough, but not so as I will explain. Several editorial decisions must be made of each received abstract: Is it rheology? Under what heading or category does it fit? Does it require editing? These I discuss below.

Is it rheology? Usually quite easy, decided by what journal it came from and keywords such as rheology, flow, non-Newtonian etc. in the title, abstract or article. But the subject of rheology is very ill-defined and appears to exist somewhere between science and engineering. Its ragged boundaries overlap with a number of others, e.g., fluid mechanics, civil and petroleum engineering, soil physics, vulcanology, and fracture mechanics. Consider the domain of experimental techniques, rapidly-changing as measurement technology evolves. Is for example the NMR imaging of flow strictly rheological? The same query relates many other experimental methods in which some property, e.g. neutron scattering, probes the flowing material. In the domain of theory, rheology and fluid mechanics merge indistinguishably. Excision is easy for papers only about inviscid flow, but many papers in fluid mechanics journals do consider viscous and non-Newtonian flow. Another excision could be made for papers about turbulence, but although laminarity is preferred in rheological property measurement, many phenomena such as drag reduction deserve abstraction in RA. So after making up an issue to be typed, doubt persists: Is rheology at all a proper subject? Have I rejected abstracts which some readers would find useful? How will I ever know? Too much thought is not afforded to Hon. Ed. in his twilight years; pragmatically (but tautologically) he defines rheology by the scope of Rheology Abstracts. This is not quite so expedient as it may appear. It permits the large and experienced readership of the BSR to disagree with the RA contents; I invite their views. As editorial definition of what is rheological is always unlikely to be absent, debate, preferably in the pages of the Bulletin, is to be encouraged.

Under what heading should an abstract fit? Having decided that a paper actually is about rheology, this decision is usually simple, but can sometimes seem wrong. For example, if a paper is about the viscoelastic but edible Xanthan polymer, does it go under Viscoelasticity, or Biological? Usually this is decided by context. However, these problems do engender another: are subdivisions into the present heads sensible and sufficient? Discerning readers will have noted that Hon. Ed. has already slightly altered the original subdivisions. This was done to simplify and to gain a better balance; other small changes for the same reasons will occur in 1995.

Does the as-received abstract need to be edited? The RA is a means for connecting the minds of its readers with the ideas of authors. Sufficient detail is required for the reader to decide only whether to obtain the whole paper.

Better value accrues from the largest number of abstracts per issue, consistent with each having sufficient detail. As received, some have far more detail than required, and these are diminished by editing. Your Hon. Ed. carefully reads more than 1000 abstracts each year. He opines that best abstracts are usually most terse. Some abstracts are so detailed there is no need to read the paper! RA Editor's plea: An abstract should describe not too much the details of the work, but say what the paper is about.

The RA goes out to BSR members and to the rest of the world's rheological community, currently in the form you receive it. It is published jointly by Elsevier and the BSR. No other Society of Rheology publishes a similar journal. It is a means of publicising and funding your Society, as rheological information for BSR members and subscribers, and as part of Elsevier's suite of scientific journals. It is therefore of some importance to discover how well RA currently performs those functions. To these ends a very brief list of questions is below. I should be very grateful to receive answers, by any way, anonymously if you wish.

Gerry Meeten, Hon Ed Rheology Abstracts
Schlumberger Cambridge Research
High Cross, Madingley Road
Cambridge CB3 0EL.
tel: 0223 325204
fax: 0223 467004
email: meeten@cambridge.scr.slb.com

QUESTIONNAIRE FOR BULLETIN READERS (Photocopy if you wish)

- (a) How useful do you rate RA? (Useless = 1; very useful=3) _____
- (b) Do you focus on few topics, or read every page?
(Few = 1; every page = 3). _____
- (c) Present A5 format ok? Prefer A4? Prefer electronic?
(A5 = 1, A4 = 2, electronic = 3) _____
- (d) Contents ? (Too few abstracts= 1, ok = 2, too many = 3). _____
- (e) If you did not receive RA as a BSR member, how much would you be prepared to pay? State figure between £0-£100 p.a. _____
- (f) Any other comments? Please write here.

INSTITUTE OF NON-NEWTONIAN FLUID MECHANICS
UNIVERSITY OF WALES, ABERYSTWYTH, BANGOR, SWANSEA

Objectives

The Institute was formed to provide a multi-disciplinary environment for meeting the challenge of modern rheological problems in industry. It brings together expertise in experimental and computational rheology, including the latest techniques for the characterisation of materials through rheometrical measurement. In addition, extensive expertise is available in the computer modelling of complex rheological flows. The Institute, which is located in three centres at Aberystwyth, Bangor and Swansea, has established numerous links with a variety of British and European industrial organisations. The 7 permanent staff of the Institute collaborate with leading rheological centres around the world and are active in various EU funded research networks. Research encompasses the whole spectrum from fundamental long-term studies to applied work concerned with problems of immediate industrial relevance.

Facilities

The Institute has well-equipped laboratories, both experimental and computational. The former has a range of modern instruments for the characterisation of materials, including controlled stress and capillary rheometers, a Weissenberg rheogoniometer and Lodge stressmeter. There are also ample facilities for custom designed experiments, including flow visualisation.

Areas of Research

1. The construction of appropriate constitutive models for representing the rheological behaviour of complex materials.
2. The rheometrical characterisation of such materials, particularly polymer solutions, polymer melts and fibre reinforced composites, leading to the derivation of material functions representing non-Newtonian behaviour of materials under shear and extension.
3. Experimental visualisation studies of complex flows of such materials using a laser technique
4. Model verification using numerical computer codes.
5. The prediction of complex industrial flows using computer codes and appropriate fluid representations.

Conferences and Courses

The Institute has its own Symposium Series, meetings of which are held each Spring and Autumn. These are usually focused on topics of particular industrial relevance and attract leading international experts from around the world. Details of forthcoming meetings may be obtained from the Institute.

Industrial Clients/Major Grants

Shell, NPL, Philips, Unilever, BICC, DSM Research, Electricity Association Technology, SERC, EU Human Capital and Mobility Programme, RAPRA, ICI

Sample Publications

1. *Rheological Phenomena in Focus*, DV Boger & K Walters, Elsevier (1993).
2. *Expansion Flows of Non-Newtonian Liquids*, P Townsend & K Walters, Chem.Eng.Sci.49 (5), 749-63 (1994).
3. *Computer Modelling of Transient Thermal flows of non-Newtonian fluids*, D Ding, P Townsend & MF Webster, Int.J.Non-Newt. Fluid. Mech. 47, 239-65 (1993).
4. *Numerical Evaluation of a Method for Determining Extensional Viscosity of Fluids using Contractional Flow Analysis*, AR Davies, IM Farah, M Rides & K Thomas, Makromol.Chem.Macromol.Symp. 68, 25-39 (1994)

For Further Information Contact:

Professor Ken Walters FRS
Department of Mathematics,
University of Wales Aberystwyth,
Penglais, Aberystwyth,
Dyfed, SY23 3BZ
Tel: 01970 622750
Fax: 01970 622777

Professor Peter Townsend
Department of Computer Science,
University of Wales Swansea,
Singleton Park, Swansea,
West Glamorgan, SA2 8PP
Tel: 01972 295398
Fax: 01972 295708

CONFERENCE REPORT

E.U. Meeting in Les Deux Alpes, 17 - 20 January, 1995

Joao M.L.I.Maia, Dept of Mathematics, U.W., Aberystwyth

This meeting took place in Les Deux Alpes, France and was a follow up to the previous ones held in Chamrousse, France (1993), Fontevraud, France (1993), Val d'Isere, France (1994), and St. Andrews, Scotland (1994). This series of meetings has been devoted to the study of the rheological behaviour of polymer solutions from the dilute solution to the melt as part of a E.U. project involving several universities in France and the U.K.

The base for these studies is the so-called S1 fluid which was prepared and supplied by the team led by Professor J.Ferguson at the University of Strathclyde; this is a solution of high molecular weight Polyisobutylene in low molecular weight Polybutene oil and Dekalin.

The contributions to the meeting were, in general, of both good quality and relevance to the present trends in rheological research. Analysing the different presentations, one noticed an apparent focusing on two or three different areas, namely the experimental and numerical studies of extensional properties in general and contraction flows in particular, the determination of relaxation spectra from dynamic mechanical data and constitutive modelling, these latter being presented in close connection to one another.

Other lectures that were given and that highlighted the spread of Rheology in today's world, regarded, among others, such different and interesting subjects as the rheometry of cream cheese and of shaving foam, the dynamics of spreading of fluids, the journal bearing problem, the extensional viscosity of lubricating motor oils, numerical simulations of wire coating polymers and the treatment of wall slip in polymer extrusion processes.

Socially this was also a rather interesting conference since the location was especially suitable to the practice of well known winter sports. This led the participants to take, quite keenly, upon themselves to perform several experimental studies on the Rheology of snow and the problem of flow on an inclined surface. Also worth mentioning is the always excellent French cuisine of which we were submitted to several demonstrations.

All these facts coupled with the overall quality and relevance of the presentations ensured that this was, indeed, a very profitable meeting for all those involved. As for myself, this was a particular interesting one since I am also working in this project and was given the opportunity to exchange results and points of view with the other delegates. Therefore I would like to thank the BSR for the travel and accommodation grant that allowed me to take part in the conference. I would also like to acknowledge J.N.I.C.T. (Junta Nacional de Investigacao Cientifica e Tecnologica) for the award of the Fellowship that is supporting my work at the University of Wales, Aberystwyth.

A REPORT ON HIGHLY FILLED MATERIALS AND
THE ACTIVITIES OF THE HIGHLY FILLED MATERIALS
INSTITUTE AT STEVENS INSTITUTE OF TECHNOLOGY
(HOBOKEN, NEW JERSEY)

Dilhan M. Kalyon
Director, Highly Filled Materials Institute

Various industrial operations necessitate the processing of a suspension or a dispersion at a solid concentration which approaches the maximum packing fraction, ϕ_m , of the solid phase, i.e., a highly filled material. The use of a multimodal size distribution increases the amount of solids which can be incorporated into a given volume, i.e., a higher maximum packing fraction in comparison to a unimodal size, whereas the use of non-spherical and fibrous particles decreases the maximum packing fraction [1].

For a bimodal size distribution the maximum packing fraction is affected by the size ratio, α , i.e., ratio of diameters of the large over small spheres, and, as shown in Figure 1, the percentage of the smaller spheres [2, 3]. Thus, the shape and size distributions of solid particles are critical in determining the maximum possible concentration of solids incorporated into a suspension. Small changes in characteristics of raw ingredients such as particle size and shape of the solid phase of highly filled materials may result in suspensions which are not processable (for example arising from the segregation of solid ingredients according to size or density in bins and hoppers) [3].

A number of industries notably solid rocket fuels and energetics, ceramics, magnetics, detergents, soaps, food products, batteries, and composites involve a variety of suspension and dispersion based products which are highly filled. The common denominator in these products is the use of the minimum amount of the liquid phase necessary to facilitate the flowability and shapeability of the suspension and the maximum amount of solids to achieve the best-possible ultimate

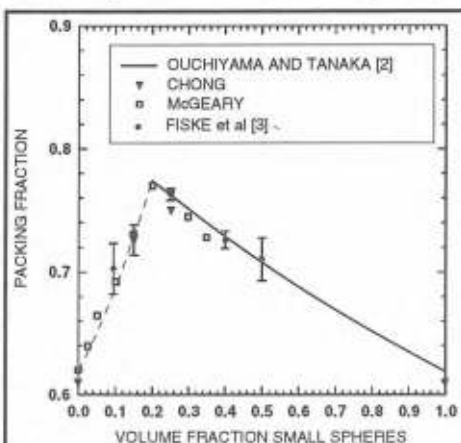


Figure 1. Maximum packing fraction versus size concentration of bimodal spherical particles at a size ratio of seven: experiments and theory.

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properties. A typical example is the use of a polymeric binder to coat ceramic particles to form a highly filled suspension which is then shaped to form the desired geometry, followed by firing-up to remove the binder and sintering of ceramic particles into a continuous phase. The minimal use of the binder by working close to the maximum packing fraction of the solid phase reduces the porosity in the final article. Overall, the high degree of fill of such concentrated suspensions introduces significant difficulties in their characterization, processing, simulation, and quality control. However, highly filled materials, regardless of the industrial application, exhibit a number of common flow, deformation and processing traits which can be understood and used for optimum design and operation of manufacturing operations. In this article, various hitherto identified traits will be outlined and ramifications on processing operations will be provided.

HIGHLY FILLED MATERIALS AT STEVENS

Highly Filled Materials Institute (HFMI) was established at Stevens in 1989 upon the encouragement of DoD and corporations to research the generic issues involved in the characterization of flow and deformation behavior, microstructure development, batch and continuous processability, property optimization and quality control of highly filled materials. This mission satisfies one of the challenging aspects of engineering research by identifying and developing interdisciplinary tools which are applicable to a multitude of industrial areas simultaneously. The Center has developed capabilities in simulation (using three dimensional Finite Element Method based source codes developed in house), rheological characterization, microstructural analysis, wettability and work of adhesion between solid and liquid phases, and characterization of ultimate properties, including electrical and magnetic properties. In the following, some of these experimental and numerical analysis tools will be described, along with some of the technologies developed.

FLOW AND DEFORMATION BEHAVIOR OF HIGHLY FILLED MATERIALS

The characterization of the flow and deformation behavior of highly filled suspensions is first and foremost complicated by the occurrence of wall slip [4-16]. The wall slip behavior of a concentrated suspension consisting of sixty three percent by volume of glass spheres in an acrylonitrile terminated polybutadiene, PBAN, matrix is demonstrated in Figure 2. The suspension sample undergoes steady torsional flow in between two parallel disks; the disk at the top is rotating and the disk at

the bottom is stationary. Before the onset of deformation, a straight line marker is placed at the free surface of the suspension and the edges of the two disks. Upon the rotation of the top disk, discontinuities appear at both the top and bottom suspension/wall interfaces, indicating wall slip.

This technique allows the determination of the slip velocity and the true deformation rate of the suspension directly in steady torsional flow [13]. The wall slip velocity during steady torsional flow is generally time-dependent [16]. With time, the deformation rate of the suspension decreases, while the shear stress and the wall slip velocity increase. When the steady state behavior is achieved, the true deformation rate is only a small fraction of the imposed apparent shear rate. The thickness of the slip layer can be estimated as a function of the viscosity of pure binder and is generally in the order of microns [9, 13, 16]. On-line analysis techniques attempting to probe various chemical or physical aspects of highly filled suspensions during rheometry and processing flows should be able to penetrate beyond the wall slip layer to characterize the bulk of the suspension—not just the slip layer.

Another method for the determination of the wall slip velocity involves the systematic changes in the surface to volume ratio in rheometry. The slip velocity can be determined from the slope of the apparent shear rate versus reciprocal diameter or gap data collected. For example, in steady parallel disk torsional flows the apparent shear rate at the edge becomes proportional to reciprocal of the gap between the two disks [7].

Plots of apparent shear rate versus the reciprocal gap height at constant values of shear stress generate straight lines with slopes equal to two times the wall slip velocity [8, 9, 13, 14]. The slope hence the slip velocity values increase with increasing wall shear stress. On the other hand, in capillary flow changing the surface to volume ratio requires that the capillary diameter be changed while keeping the length/diameter ratio of the capillary a constant. Upon wall slip, the apparent shear rate varies linearly with reciprocal of capillary diameter at constant wall shear stress with a slope equal to eight times the wall slip velocity [4, 9].

The typical steady-state slip velocity at the wall versus shear stress behavior of two highly filled suspensions, characterized with torsional and capillary flows, are shown in Figure 3. The wall slip velocity

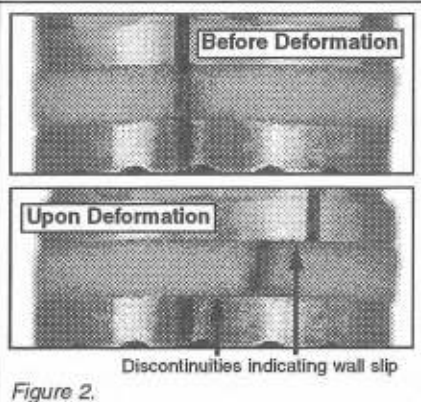


Figure 2.

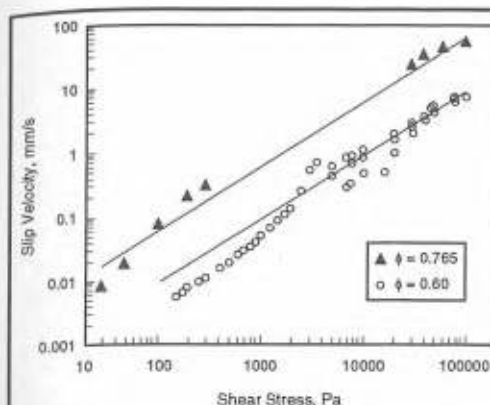


Figure 3. Wall slip velocity versus shear stress of two suspensions with 60% and 76.5% by volume solids.

increases with wall shear stress [9, 13]. The wall slip behavior of highly filled materials can be characterized in such viscometric flows and used for first-order analysis of 2-D and 3-D processing flows as an interfacial dynamic boundary condition.

The thickness of the deforming slip layer changes as a function of binder and solid phase characteristics. Attempts to eliminate wall slip during deformation by roughening the walls of

processors can generate fracture surfaces (discontinuities of velocity) in highly filled materials [16].

SOLID-LIKE BEHAVIOR WITH WALL SLIP

In capillary flows the relative effect of the slip flow on the overall flow rate can be ascertained by the characterization of the Q_s/Q ratio where $Q_s = (\pi/4)D^2U_s$ is the volumetric flow rate due to slip and Q is the volumetric flow rate given by $Q = (\pi/4)D^2V$. When the mean velocity of the suspension in the die, V , becomes equal to the slip velocity, U_s , for a capillary die with a diameter, D , the suspension flows without deformation, that is, as a plug, lubricated at the wall.

Q_s/Q versus wall shear stress behavior in capillary flow of two suspensions with different particle size distributions are shown in Figure 4. The 60 percent by vol. solids suspension flows as a plug above a wall shear stress value of 40 kPa, whereas the suspension with 76.5 percent by vol. solids exhibits plug flow at wall shear stress values which are smaller than 10 kPa [9, 13].

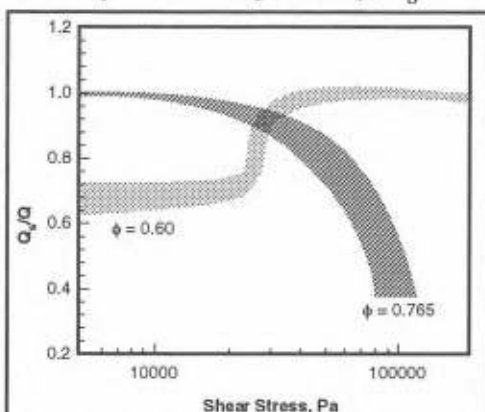


Figure 10. Ratio of volumetric flow rate due to slip, Q_s over volumetric flow rate for capillary flow, Q , of two suspensions with 60% and 76.5% by volume solids.

These observations indicate that highly filled suspensions become solid-like in various flow regimes. Solid-like behavior at wall shear stress values smaller than a yield stress is defined as viscoplasticity and is related to the formation of a temporary network which is destroyed when the shearing stress exceeds the yield stress. The development of solid-like behavior above a critical wall shear stress is associated with dilatancy [17] possibly arising from the radial migration of solid particles away from the wall of the die [18-20] and subsequent interlocking to

establish solid-like behavior. Formation of solid-like plugs with lubrication layers at the wall renders it difficult to achieve adequate mixing and processing of highly filled suspensions.

Figure 5 illustrates the viscoplasticity of a suspension with 76.5% by volume solids [13]. Upon rotation of the disk at the top, the suspension initially deforms. However, further angular displacement of the rotating disk induces only wall slip adjacent to the walls and the suspension no longer deforms under the prevailing conditions of constant shear stress. The inseparable nature of wall slip and solid-like behavior is also indicated.

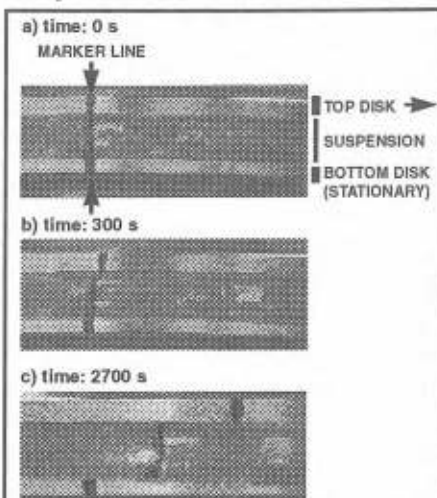


Figure 5. Demonstration of the viscoplasticity, i.e., solid-like behavior in steady torsional flow at a shear stress smaller than yield stress.

FLOW INSTABILITIES OF HIGHLY FILLED SUSPENSIONS

Pressure driven flows of highly filled suspensions can give rise to flow instabilities associated with the migration of the binder in the direction of the pressure gradient, which drives the flow [21-24]. Such demixing of the ingredients of the formulation of highly filled suspensions affects the quality of the degree of mixedness of the suspension and hence its ultimate properties. It renders the continuous processing operation unstable and also poses a safety threat in processing of energetic suspensions. The use of gear pumps or sensors with tight converging sections also become prohibiting.

The basic driving force of flow instabilities in the flow of highly filled materials is the axial migration of the binder, "filtering," superimposed on the pressure-induced bulk flow of the concentrated suspension. Upon axial migration concentration gradients develop in the suspension

flowing under pressure. The axial migration of the binder phenomenon is demonstrated in Figure 6 [24]. Here, upon the pressure induced flow of a suspension in a cylindrical reservoir connected to a capillary die, the suspension loses some of its binder content and develops a concentration gradient in the axial flow direction, z , between the plunger which drives the flow and the die.

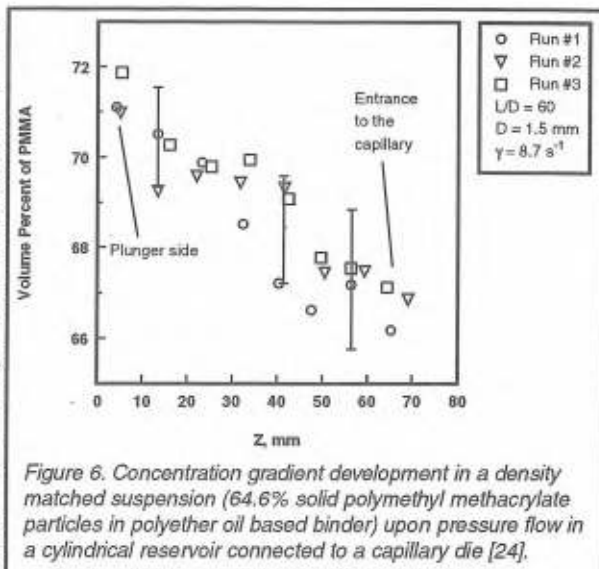


Figure 6. Concentration gradient development in a density matched suspension (64.6% solid polymethyl methacrylate particles in polyether oil based binder) upon pressure flow in a cylindrical reservoir connected to a capillary die [24].

Under severe unstable flow conditions the pressure necessary to extrude the suspension oscillates while growing unbounded with time. The time periodic oscillations in extrusion pressure are related to the time periodic mechanism of formation of a mat of solids at the capillary or die and its break-up which occurs concomitant with the filtration of the binder in the axial direction [22]. The axial migration of binder in converging flow generally prevents the use of gear pumps and sensors where suspension is dragged into small clearances for highly filled materials.

The onset of flow instabilities associated with mat formation and filtering of the binder can be predicted with reasonable accuracy by comparing the filtration velocity (average velocity of the binder through a packed bed of solids) of the binder with the wall slip velocity under the generally prevailing plug flow conditions [22,24]. The flow generally becomes unstable when the filtration velocity V_m becomes greater than the slip velocity of the plug. Obviously in the processing of highly filled suspensions the filtration of the matrix and thus the unstable region should be avoided [21-24]. Otherwise, the additional loss of the binder due to axial migration at solid loading levels, which are very close to the maximum packing fraction will render the suspension unprocessable. The unstable region in converging flows can be avoided by the proper selection of the production rate and the geometry of the channel through which the suspension is flowing.

AIR ENTRAINMENT EFFECTS IN PROCESSING OF HIGHLY FILLED SUSPENSIONS

Since the formulation of a highly filled suspension involves a volume fraction of solids which approaches the maximum packing fraction of the solid phase, the incorporation of even small concentrations of air, makes a significant difference in the rheological behavior and hence the processability of highly filled suspensions [25-29]. The shear viscosity of the suspension decreases and wall slip velocity values increase with the incorporation of air into the suspension [28].

The amount of air entrained into the suspension increases at partially full regions in comparison to suspension samples found at the completely full sections of processors [26]. For example, the density of samples collected from the reversely configured screw sections of a twin screw extruder (which necessitate completely full mixing volume) are greater than those of the samples collected from the partially full sections of the same extruder i.e., at forwardly configured screw sections [26]. The air entrained into the suspension also affects the development of the slip layer (binder rich region found adjacent to the wall) of the suspension during die flows [30]. Under moderate die pressures, pockets of air cling to the wall momentarily and are spread out to be later dragged-on by the bulk of the suspension [30].

CONTINUOUS PROCESSING OF HIGHLY FILLED SUSPENSIONS

Currently continuous processing techniques i.e., single and twin screw extrusion have surpassed batch processing in many processing applications where the ingredients of a highly filled material are interspersed in each other (distributive mixing), the physical properties of one or more of the components are altered (dispersive mixing, such as a decrease in particle size), the air or solvent content of the suspension is reduced under vacuum (devolatilization), and the suspension is pressurized (for shaping in a die or mold); all within the confines of a single processor with properly selected screw and barrel elements [31]. Such versatile continuous processors provide a better surface to volume ratio and facilitate real-time, on-line process control and easier pollution prevention in comparison to batch mixers.

However, due to the peculiar nature of the flow and deformation behavior of highly filled materials their continuous processing is a special challenge [32-41]. Especially the wall slip behavior needs to be incorporated into the mathematical modeling of their processing behavior [32, 33, 35, 38, 39]. Figure 7 shows the typical effect of the ratio of the wall slip coefficient at the screw surface over the slip coefficient at the barrel

developed various technologies which are of immediate relevance to the public at large. These include apparati and methods for mitigation of the magnetic fields generated by extremely low frequency sources including distribution and transmission lines, and encapsulation technologies for disposal of very toxic liquids including chemical munitions [46-48]. Our EMF shielding technology is an offshoot of our involvement in tailoring of the electrical and magnetic properties of conductive and magnetic components which are molded or extruded [49-52] and resulted upon a rigorous marriage of the use of simulation (solution of Maxwell Equations using FEM [53]), and material characterization, processing and testing [49-52]. Our technology base for the concomitant neutralization of very toxic liquids [48] including chemical munitions and encapsulation of neutralization products into extruded non-hazardous waste relied on our understanding of continuous processing of highly filled materials incorporating a high degree of fill of gel based particles surrounded by a thermosetting binder.

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NEW NEW NEW NEW NEW

POLYMER MELT RHEOLOGY CONFERENCE
UNIVERSITY OF WALES
ABERYSTWYTH
3 - 6 September 1995

This meeting is being arranged by the University of Wales Institute of Non-Newtonian Fluid Mechanics and is being sponsored by the British Society of Rheology as their annual autumn Conference, by the Materials and Testing Group of the Institute of Physics and by the UK Department of Trade and Industry through the National Physical Laboratory. The intention is to attract international participation.

The aim of the meeting is to establish the theoretical and related experimental state of knowledge of the rheology of polymer melts, both in understanding their behaviour in varied deformation conditions, and in providing a sufficient characterisation of behaviour to progress the development of modelling of polymer processing. Innovative computer modelling of flow will be included.

The opening lecture is to be given by Sir S.F. Edwards FRS. Keynote papers are expected to be presented by: M. Crochet (Belgium), M. Denn (USA), J. Ferguson (UK), M. Mackley (UK), J. Meissner (Switzerland), M.H. Wagner (Germany) and H. Winter (USA).

The local Conference Committee comprises A.R. Davies, K. Thomas and K. Walters FRS.

An early indication of proposed attendance is requested, and offers of papers with title and a short abstract are required by Monday 15th May 1995. A programme for accompanying persons will be arranged if sufficient interest is indicated.

Address for Enquiries and Correspondence:

Professor Ken Thomas
Department of Mathematics,
University of Wales,
Penglais, Aberystwyth
Dyfed, SY23 3BZ, UK

Tel: +44 (0) 1970-622768 Fax: +44 (0) 1970-622777

CONFERENCE PROGRAMME

(Session timings are provisional)

Sunday	3 Sept	14.00 - 18.00	Registration in Rosser Hall Reception
		18.00 - 21.00	Fork Buffet in Rosser Hall Bar
		18.00 - 21.00	Registration in Rosser Hall Bar
			Accommodation in Rosser Hall/Cwrt Mawr Hall
Monday	4 Sept	08.00 - 09.00	Breakfast (all meals in Penbryn Hall)
		09.00	Opening Lecture and Session
		Mid-morning	Coffee
		12.45	Lunch
		14.00	Session
		Mid-afternoon	Tea
		18.00	British Society of Rheology AGM
		19.30	Dinner
Tuesday	5 Sept	08.00 - 09.00	Breakfast
		09.00	Session
		Mid-morning	Coffee
		12.45	Lunch
		14.00 PROMPT	Conference visits leave Rosser Hall
		Mid-afternoon	Tea
		19.30	Reception
		20.00	Dinner
Wednesday	6 Sept	08.00 - 09.00	Breakfast
		09.00	Session
		Mid-morning	Coffee
		12.45	Lunch
		14.00	Session
		Finish	Not later than 16.00 for tea.

A programme for accompanying persons will be arranged if sufficient interest is indicated - details on registration.

OFFERS OF PAPERS

Offers of papers with title and a short abstract are required by
Monday 15th May 1995.

22 REGISTRATION

Each Conference member should complete a separate registration form (original copied if necessary). Accompanying persons can be entered on the same form; please note the possible alternative accommodation in non en-suite twin rooms if needed. Accommodation is also available before and after the meeting.

PAYMENT OF FEES

Payment of accommodation and registration fees may be made by one of the following methods:

- by cheque drawn in Sterling on a UK Bank and made payable to 'UCW, Aberystwyth'
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TRAVEL

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Trains from London Euston to Aberystwyth - change at Birmingham (New Street) or Wolverhampton - are presently as follows (but timings may change for September 1995).

Sunday 3rd September

Wednesday 6th September

London Euston	10.45	12.45	15.45	↑	18.27	20.59	23.16	01.14
B'ham Intl.	12.39	14.39	17.26		16.55	19.22	20.52	22.59
B'ham (New St)	13.13	(15.01)	18.44		16.23	18.48	20.24	22.25
Wolverhampton	13.43	15.45	19.02		16.03	18.26	20.05	22.04
Shrewsbury	14.39	16.29	20.35		15.19	17.19	19.19	21.21
Aberystwyth	16.27	18.17	22.11	↓	13.31	15.31	17.31	19.31

DEGREE OF MIXEDNESS

The microstructure of highly filled materials which controls their flow and deformation behavior as well as their various ultimate properties like electrical, magnetic and mechanical properties are affected foremost by the degree of interspersing of various ingredients of the formulation and the physical properties of the ingredients (such as particle size of solids which can change during processing).

Can the degree of mixedness of highly filled materials in batch and continuous mixers be predicted and characterized quantitatively? The challenge is to determine proper locations for minor components to be input into the processor and selection of appropriate geometry and operating condition for efficient mixing without deteriorating various properties of the suspension. Various simulation techniques, especially those which utilize the tools of dynamics, can be used assuming that the numerical tracers are passive and non-diffusive and the microstructure and hence the rheology of the suspension does not change during the processing flow [36, 37, 40, 41]. On the experimental side, we have developed two techniques, both based on x-ray analysis to characterize the volume ratios of various ingredients as a function of the scale of examination and location [43].

We utilize the variance of the ratio of the minor to the major phases as a quantitative measure of degree of mixedness. Figure 8 illustrates our x-ray based experimental technique [43]. The variation of the volume ratios of a plasticized binder, cellulose acetate butyrate, (CAB) over the solid content, i.e., RDX and HMX powders at various locations in an extruded grain are determined. Two samples were characterized. The first sample was processed in a batch mixer and then ram extruded, whereas the second sample was extruded and shaped in a twin screw extruder.

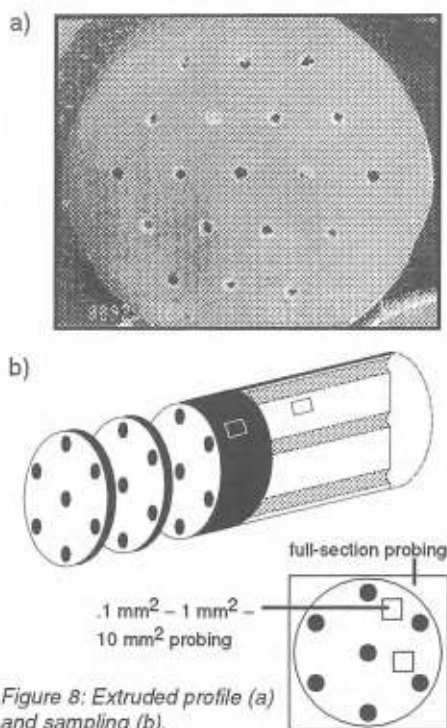


Figure 8: Extruded profile (a) and sampling (b).

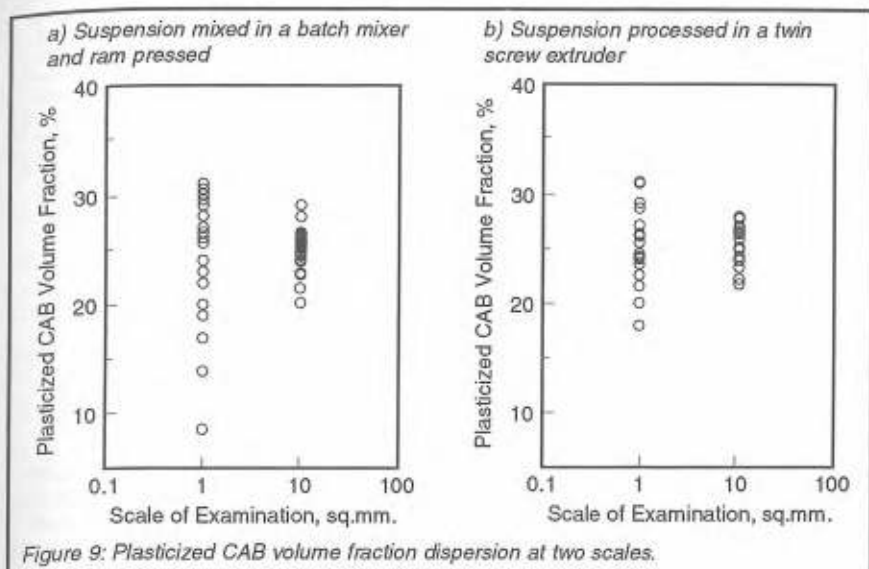


Figure 9 shows that the volume fraction of the binder, CAB, varies considerably around the mean at different locations in the mixture for the batch mixed sample. On the other hand, a narrow distribution around the mean is obtained with the continuously processed suspension sample. The difference becomes more significant at the smaller scale of examination of 1 mm^2 . The variance, s^2 , of the volume fraction of the binder from the mean, $\bar{\tau}$, is used to define a coefficient of variation, $s/\bar{\tau}$, (with the maximum variance of completely segregated sample given by: $s_0^2 = \bar{\tau}(1-\bar{\tau})$) and we define the mixing index as $1-s/s_0$.

The mixing index values range from zero for a completely segregated sample (unmixed) to one for a perfect mixture with zero variance around the mean. The mixing index values for the batch mixed sample of Figure 9 is 0.85 and the twin screw processed sample is 0.92 at a scale of examination of 1 mm^2 , indicating the superior distributive mixing capability of the continuous processor. This analysis technique for the first time allows the quantitative characterization of the degree of mixedness of suspension samples and facilitates the experimental determination of proper mixing geometries and conditions for highly filled materials.

EXAMPLES OF TECHNOLOGIES DEVELOPED

Besides new techniques for characterization of wall slip, flow instabilities, on-line rheology [45], simulation methodologies for processability and degree of mixedness of highly filled materials, we have also

surface, ϕ , on the operating curve of a single screw extruder [32]. At constant mass flow rate the pressurization capability decreases with increasing slip coefficient ratio, ϕ . The wall slip behavior and hence processability of highly filled materials can indeed be affected to some extent by the choice of materials of construction especially with different material use on moving and stationary surfaces

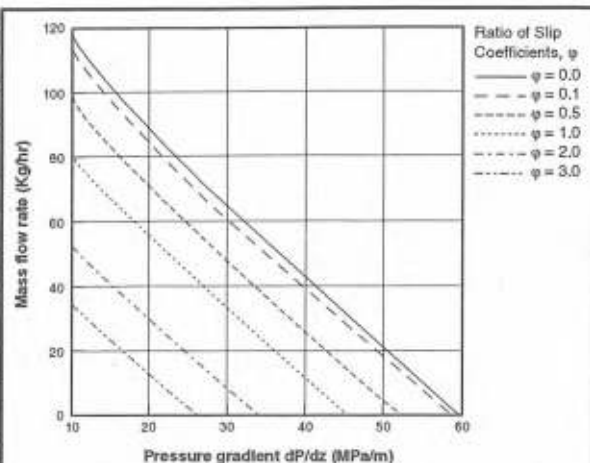


Figure 7. Operating curve (pressurization rate versus production rate) of a single screw extruder as affected by the ratio of wall slip coefficients at screw and barrel surfaces, ϕ [32].

An additional difficult aspect of continuous processing arises from the dispersive mixing associated with the exertion of high stress levels on small fractions of the suspension by forcing repeatedly through the small gaps found between screws or the screw and the barrel elements during continuous processing [34, 40]. For example, relatively high stress magnitudes are exerted on the suspension at such gaps found in the kneading disc sections of co-rotating twin screw extrusion flows [34, 37, 40]. The physical properties, including particle size distribution, of the suspension experiencing the higher stress magnitudes can become significantly different than the rest of the suspension.

The microstructure of the suspension evolves continuously as a function of flow and deformation history in the processor. Microstructure development encompasses the degree of mixedness of the ingredients, migration of particles based on shear rate and concentration gradients, interlocking of particles to form solid-like plugs, encapsulation of binder locally upon interlocking, formation of binder-rich layers at high shear rate regions, entrainment of air/solvent gases, and lubrication of surfaces with air/gases. However, these changes currently cannot be accommodated in the simulation of the three dimensional flow field of the processors.

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45. D. M. Kalyon and H. S. Gokturk, "Adjustable Gap Rheometer," U.S. Patent #5277058; issued on Jan. 11, 1994.
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47. D. M. Kalyon, H. S. Gokturk, S. Railkar, "Electric Power Transmission System and Method of Asymmetric Transmission of Power to Mitigate Magnetic Fields," U.S. Patent and Trademark Office; application accepted; Serial no. 062,188, May 1993
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49. J. S. Sun, H. S. Gokturk and D. M. Kalyon, "Volume and Surface Resistivity of Low Density Polyethylene Filled with Stainless Steel Fibres," *Journal of Materials Science*, 28 (1993) 364.
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NEWS OF EUROPEAN SOCIETIES

COMBINED MEETING OF THE BELGIAN AND DUTCH SOCIETIES OF RHEOLOGY

The Belgian and Dutch Societies of Rheology will be holding a joint meeting on May the 3rd, 1995, at the Academisch Genootschap in Eindhoven on the topic of 'Relation Microstructure-Rheology for Complex Materials'.

The Programme includes the following papers:

'Flow Induced Crystallization of Polypropylene Melt' F.Chambon, Exxon Chemical Europe, Belgium.

'Transient Viscosity Measurements on a Weakly Aggregation Dispersion after a Step Down in Shear Rate'. D. van den Ende, A.A.Potatin, R.de Rooij & J.Mellema.
Rheology Group, University of Twente, The Netherlands.

'Transient Behaviour of Model Polymer Blends'. P.Moldenaars,
Dept of Chem. Eng., Katholieke University Leuven, Belgium

'Prediction of Flow-Induced Mechanical Properties of Composite Materials'.
V.Verleye, G.Lielens, P.Pirotte, F.Dupret & R.Keunings. CESAME,
Université Catholique de Louvain, Belgium.

'Structure of Fat Crystal Aggregates as Deduced from Steady Shear Viscometry'.
W.Kloek, T. van Vliet, P.Walstra & B.Hart. Dept of Food Science,
Wageningen Agricultural University, The Netherlands.

'Brownian Dynamics of Polymeric Networks'. B.H.A.A.van den Brule.
Shell Research B.V., Rijswijk, The Netherlands.

For further information, contact:

Marleen van Boxtel,
Eindhoven University of Technology,
P.O.Box 51, W.hoog O.140, 5600 MB Eindhoven,
The Netherlands.

Tel: +31 40 472851, Fax: +31 0 447355

RHEOLOGENTAGUNG 1995

Two day Meeting of the German, Austrian and Swiss Rheology Societies
Berlin, 22 - 23 May 1995

This two day meeting of the three societies is being held at the Logenhaus Berlin and will be run in three parallel sessions with some 75 presentations planned. The Conference language is German. The meeting includes the AGM of the Deutschen Rheologischen Gesellschaft and the awarding of the Rheologiepreise 1995 der Zeitschrift Rheology.

For further information contact:

Prof. Dr K.-H.Habig

Bundesanstalt für Materialforschung und -prüfung,
Unter den Eichen 87, 12205 Berlin, Germany

LETTER TO THE EDITOR

A reply to my letter to European Societies expressing our wish to become more involved in Europe and to publish more European news.

Dear Sir,

I apologize for the delay in replying to your letter of 31st January. Actually, I was involved in the preparation of our first issue of the Bulletin of the Spanish Group of Rheology. Enclosed you have a copy of the bulletin. I think this bulletin gives an answer to most of your questions. Moreover, since I am in charge of editing the bulletin, I offer myself as a possible contact for the scientific activities and reports relative to the Spanish Group of Rheology.

In relation to the expansion of the different bulletins or newsletters into a European Bulletin, I think it would be very well received among the Spanish members. However, I wonder if it wouldn't be better to consider this European Bulletin under the umbrella of the possible future European Rheology Society. In any case, I agree with the general idea, as well as with the exchange of information from our respective groups or societies. This would contribute to an improvement of the diffusion of Rheology in Europe.

Thank you very much for your kind letter. If you need any further information do not hesitate in contacting me.

Yours sincerely,

Prof A. Guerrero, Secretary, Spanish Group of Rheology,
Dept of Chem. Eng., University of Sevilla.

Contacts from current lists of officers of European Rheology Societies.

BELGIAN GROUP OF RHEOLOGY

President

Prof. P. Moldenaers,
Dept of Chem. Eng.,
K.U.Leuven, de Croylaan 46,
B-3001 Heverlee (Leuven)
Tel: 016 /32 23 59 Fax: 016 /32 29 91
e-mail:
paula.moldenaers@cit.kuleuven.ac.be

Secretary

Ir. J. Vernant,
Dept of Chem. Eng.,
K.U.Leuven, de Croylaan 46,
B-3001 Heverlee (Leuven)
Tel: 016 /32 23 55 Fax: 016 /32 29 91
jan.vermant@cit.kuleuven.ac.be

GROUPE FRANÇAIS DE RHEOLOGIE

President

Prof. J.M. Piau,
Laboratoire de Rhéologie,
Domaine Universitaire,
BP no. 53 X,
38041 Grenoble Cedex,
France
Tel: 76 82 51 70 Fax: 76 82 51 64

Secretary

J. Bouton,
Société RHEO,
99 route de Versailles
91160 Champlan,
France
Tel: 64 54 01 01 Fax: 64 54 01 87

NORDIC RHEOLOGY SOCIETY

President

Ole Kramer,
Københavns Universitet,
Universitetsparken 5,
DK-2100 København,
Denmark

Secretary

Mats Stading,
SIK-Biofysik,
Box 5401,
S-402 29 Göteborg,
Sweden

SPANISH GROUP OF RHEOLOGY

President

Crispulo Gallegos
Dpto. Ingeniería Química,
Fac. Química,
Universidad de Sevilla,
c/ Prof. García González, s/n
41012 Sevilla, Spain
Tel: 95 4557179 Fax: 95 4557134

Secretary

Antonio F. Guerrero
Dpto. Ingeniería Química,
Fac. Química,
Universidad de Sevilla,
c/ Prof. García González, s/n
41012 Sevilla, Spain
Tel: 95 4557179 Fax: 95 4557134

BRITISH SOCIETY OF RHEOLOGY

Revenue Account for the Year Ended 30th June 1994

	1994	1993
	£	£
EXPENDITURE		
Council expenses	4,643	3,558
Bulletin production costs	3,985	5,047
Expenditure by Officers		
Secretary	385	906
Treasurer expenses	118	38
Membership Secretary and circulation	<u>395</u>	<u>1,514</u>
	898	2,458
Professional fees	250	250
Insurance	144	120
Awards	1,489	397
Weissenberg lecture	-	969
Miscellaneous	9	694
Conferences (see below)	745	-
Student grants	1,020	200
Working groups	127	-
Cardnet charges	159	154
Depreciation :		
Word processors	<u>392</u>	<u>1,297</u>
	13,861	15,144
INCOME		
Annual subscriptions & entrance fees	5,049	4,753
Publisher - Rheology Abstracts	6,405	6,746
Advertising	2,115	2,622
Bulletin subscriptions	300	317
Book royalties	18	-
Sale of ties	-	56
Bank interest	1,308	2,038
Conferences (see below)	-	2,542
Donation of Biorheology Award	<u>500</u>	<u>-</u>
	15,695	19,074
EXCESS OF INCOME OVER EXPENDITURE	<u>(1,834)</u>	<u>(3,930)</u>
	<u>13,861</u>	<u>15,144</u>
CONFERENCES ACCOUNT		
Surplus or (deficit) after expenses		
Liverpool, 1990	-	88
Manchester, 1993	(54)	354
London, 1991	-	569
Cambridge, 1992	(691)	931
Donations	<u>-</u>	<u>600</u>
	<u>(745)</u>	<u>2,542</u>

ENGINEERING RHEOLOGY

13th to 17th November 1995

A one week course on Engineering Rheology will take place at the University of Strathclyde from Monday 13th to Friday 17th November, 1995. The objectives of the course are to provide a thorough understanding of the mechanisms of flow encountered in processing non-Newtonian fluids, the techniques available for characterising these fluids, and the consequences of fluid rheology in the design of process machinery and the performance of the final product.

The course will consist of both lectures and laboratory work. The lectures will be given by acknowledged experts from industry and academia. Course work will ensure hands on experience on a wide variety of rheological instrumentation and the interpretation of data obtained. The emphasis throughout will be on the rheology of fluid processing. Some knowledge of rheology will be desirable, but not essential. The course will be suitable for scientists and engineers working in research, product development or production in a wide range of commercial enterprises; the plastics, pharmaceutical, oil, food and textile industries being a few examples.

The fee for the course will be £850. Ample accommodation at several grades is available within easy walking distance of the University, which is situated in the centre of Glasgow.

Further details can be obtained by completing the attached form (or a photocopy) and returning it to Professor J. Ferguson or Dr N. Hudson at the address given below.

.....
To: Prof. J. Ferguson, Department of Pure and Applied Chemistry,
University of Strathclyde, 295 Cathedral Street,
Glasgow, G1 1XL, Scotland.

Tel: +44 (0) 141-552-4400 ext 2161 Fax: +44 (0) 141-552-5664
e-mail: n.e.hudson@strath.ac.uk

Please send details to:-

NAME (Mr, Mrs, Miss, Ms, Dr, etc) _____

Address _____

Tel No. _____ Fax: _____



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BRITISH SOCIETY OF RHEOLOGY

Balance Sheet as at 30th June 1994

	1994	1993
	£	£
FIXED ASSETS		
Word processors		
At cost at 1st July 1993	5,805	5,805
Depreciation to date	<u>(5,805)</u>	<u>(5,413)</u>
	-	392
CURRENT ASSETS		
Cash at bank		
Premier Interest account	31,520	34,212
Current accounts	<u>1,426</u>	<u>2,142</u>
	32,946	36,354
Sundry debtors and prepaid expenses	<u>7,112</u>	<u>2,805</u>
	40,058	39,551
CURRENT LIABILITIES		
Sundry creditors	<u>250</u>	<u>1,577</u>
	39,808	37,974
SCOTT-BLAIR LEGACY FUND ASSETS		
Premier Interest account	11,691	11,254
Owed to General account	<u>(675)</u>	<u>-</u>
	<u>11,016</u>	<u>11,254</u>
	50,824	49,228
GENERAL FUND		
At 1st July 1993	37,974	34,044
Excess of income over expenditure in the year	<u>1,834</u>	<u>3,930</u>
	39,808	37,974
SCOTT-BLAIR LEGACY FUND		
Balance at 1st July 1993	11,254	11,287
Bank interest	437	<u>669</u>
	11,691	11,956
Expenses	<u>(675)</u>	<u>(702)</u>
	<u>11,016</u>	<u>11,254</u>
	50,824	49,228

R.E.Carter, Hon. Treasurer
Alfred Simmons and Co., Auditors

CONFERENCE ANNOUNCEMENTS

Ninth International Workshop on Numerical Methods in Non-Newtonian Flows

Llyndir Hall, Rossett, Wales, 19-22 April, 1995

This International Workshop is sponsored by the University of Wales and the British Society of Rheology.

Papers on the following topics have been included in the programme. Numerical Simulation, Time-dependant Flows, The Journal Bearing Problem, Flow Past a Sphere, Stability, Viscoelastic Singularities, Non-isothermal Flows, High Order Methods, Experiments and General Topics.

The meeting also includes a Mediaeval Banquet at Ruthin Castle, A Conference Dinner, a coach trip to Llandudno and the presentation of the British Society of Rheology Gold Medal and Annual awards. Professor Marcel Crochet will present a Gold Medal Award lecture entitled 'Numerical Simulation of the Flow of Polymer Solutions with the FENE-P Model' at 9 a.m. on Friday, 21st April. Dr Gareth McKinley will present the BSR Annual Award lecture entitled 'Steady and Transient Motion of a Sphere Sedimenting through Shear-thinning and Constant-viscosity Elastic Fluids' at 9 a.m. on Saturday, 22nd April.

For further details contact:

Dr T.N.Phillips,

Dept. of Mathematics, University of Wales,
Aberystwyth, Dyfed, SY23 3BZ

My **apologies** to members that by the time this bulletin reaches you, the above meeting will already have taken place.

Editor

THE RECENT DEVELOPMENTS IN RHEOLOGY

30th ANNUAL MEETING OF THE
GROUPE FRANCAIS DE RHEOLOGIE (GFR)

organised in collaboration with the
BRITISH SOCIETY OF RHEOLOGY

BORDEAUX 13 - 15 SEPTEMBER 1995

OBJECTIVES OF THE MEETING:

Rheology is in constant evolution on a theoretical, numerical or experimental level. This development is due to its large application fields and to the diversity and complexity of the materials studied.

The thirtieth meeting of the GFR aims at bringing together scientists and representatives of the industrial world who are interested in the latest advances in rheology. It also intends to reinforce existing collaborations between French and British rheologists. This meeting will be an opportunity to present and confront all the recent works and innovations in the area of rheology. However a few specialised sessions will be devoted to the following topics:-

- | | |
|-----------------------------|---|
| 1 - Rheophysics | 2 - Food rheology |
| 3 - Industrial rheology | 4 - Rheology and wood mechanics |
| 5 - Rheology of suspensions | 6 - Interface effects in solid rheology |

The deadline for the offer of papers (1st April 1995) will have passed by time you receive this bulletin. The text of selected papers should be submitted before the 15th June 1995 and the deadline for registration is: 1st July 1995

For further information please contact:

Secretariat of the 30th meeting of the GFR
MASTER - ENSCPB
Université Bordeaux 1
351 cours de Libération
33405 TALENCE CEDEX
FRANCE

Tél: (33) 56.84.66.88 Fax: (33) 56.84.66.68

WORKSHOP ON DYNAMICS OF COMPLEX FLUIDS

A six month research programme at the
Isaac Newton Institute for Mathematical Sciences,
University of Cambridge, United Kingdom

January to June, 1996.

Organisers: TCB McLeish (Leeds), JRA Pearson (Cambridge), K. Walters (Aberystwyth)

Background

The Isaac Newton Institute for Mathematical Sciences is an international research centre, sponsoring six-month visitor programmes in topics across the whole spectrum of mathematical research. At any one time the Institute can accommodate around 20 visitors in each programme, with larger numbers visiting for short periods (such as for conference sessions). Long-term participation will be by invitation, but enquiries are welcome from postdoctoral research workers. The parallel programme will be on Computer Security, Cryptology and Coding Theory.

Theme of the Programme

Many fluids of industrial, biological and environmental importance (e.g. molten plastics, salad dressings, whole blood, sinovial fluid, fluidised sediments) respond in a complicated fashion when deformed. The reasons for this complexity can be traced back to their molecular structure and to the hydrodynamic forces acting between molecules. The programme will bring together experts who seek to relate flow behaviour to structure and those who seek to predict flow fields of such fluids in complex geometries, with particular reference to polymer melts, polymer solutions, liquid crystals and colloidal suspensions. This involves modelling on a wide range of length (and associated time) scales, i.e. from molecular dynamics to large scale continuum mechanics. Most of the mathematical problems that arise involve non-linear differential, integro-differential or integral equations; a full range of analytical and numerical techniques has to be employed to obtain solutions.

Structure of the Programme

Each month will focus on a particular theme. These themes, which may include specific workshops, reflect the proposed pattern of areas of concentration:

The first three meetings will have an emphasis on the microscopic features of these liquids

January:	Polymeric systems
February:	Surfactants and liquid crystals
March:	Colloids
April/May:	Constitutive modelling and boundary-value problems
May/June:	Computational issues

Provisional arrangements for meetings planned within the workshop so far are as follows:

- January 8-12: Meeting on experimental problems. This meeting will present and discuss experimental observations that need analysis and interpretation and will cover microscopic and macroscopic behaviour at all levels.
- March 24 - April 4: *Summer School* on theoretical challenges in complex fluids.
- March 26-28: Meeting on colloid aspects of complex fluids., jointly with the Colloid and Interface Science Group.
- April 15-19: Meeting on constitutive relations and their applications to complex flow problems.
- June 24-28: Meeting on computational issues. This meeting would seek to bring together micro-, meso- and continuum-approaches and to examine the role of "intermediate" constitutive relations in modelling flow and other physical processes.

In addition to these meetings, many other one or three day workshops are planned and members may wish to take advantage of a number of high profile international visitors who will be resident at the Isaac Newton Institute in Cambridge during the period of the workshop.

Participation

The following are expected to participate in the programme:

for three months or more:

JF Brady, ME Cates, M Doi, JD Goddard, EJ Hinch, R Kuenings, RG Larson, LG Leal, G McKinley, TCB McLeish, JRA Pearson, M and Y Renardy, MH Wagner, K Walters, LR White.

for shorter periods:

R Buscall, AR Davies, P-G de Gennes, VM Entov, G Fredrickson, E Guyon, P Higgs, J-F Jaonny, DD Joseph, AI Leonov, MR Mackley, G Marrucci, H-C Öttinger, JM Rallison, JC Saut, AN Semenov, JD Sherwood, RI Tanner, P Townsend.

General Enquiries

For enquiries related to the programme, please contact:

JRA Pearson, Schlumberger Cambridge Research,
Madingley Road, Cambridge, CB3 0EL, UK
Tel: +44 (0)1223 325385 Fax: +44 (0)1223 315486
E-mail: pearson@cambridge.scr.slb.com

CONFERENCE DIARY

DATE	PLACE	DETAILS
19-22/4/95	Rossett, Wales	'Ninth International Workshop on Numerical Methods in Non-Newtonian Flows' , Contact: Dr T.N.Phillips, Dept. of Mathematics, University of Wales, Aberystwyth, Dyfed, SY23 3BZ
3/5/95	Eindhoven The Netherlands	Combined Meeting of the Belgian & Dutch Societies of Rheology Relation Microstructure Rheology for Complex Materials. Contact: Marleen van Boxtel. Eindhoven University of Technology. P.O.Box 51, W.hoog O.140, 5600 MB Eindhoven, The Netherlands. Tel: +31 40 472851, Fax: +31 0 447355
3/5/95	Coventry, UK	'Thickeners and Thickening by Association' , Awareness Forum Contact: Dr Cheryl Flynn, Bristol Colloid Centre, University of Bristol, Bristol, BS8 1TS Tel/Fax: 0117 929 8388
15-17/5/95	Lyon, France	Euromech 334, 'Textile Composites & Textile Structures' Contact: Prof. P. Hamelin, Laboratoire Mécanique et Matériaux, Université Lyon I, IUT A - Génie civil 43, Boulevard du 11 Novembre 1918, F-69622 Villeurbanne Cedex, France Tel: (33) 78.94.88.97 Fax: (33) 78.94.69.06
22-23/5/95	Berlin, Germany	Rheologentagung 1995. Two day Meeting of the German, Austrian and Swiss Rheology Societies. Contact: Prof. Dr K.-H.Habig, Bundesanstalt für Materialforschung und -prüfung, Unter den Eichen 87, 12205 Berlin, Germany. Tel: (030) 81 04 10 39
10-20/7/95	Durham, UK	The Durham Mathematical Symposium on Liquid Crystals. Contact: Dr Iain Stewart/Prof Frank Leslie, University of Strathclyde. Tel: 0141 552 4400 Ext 8128

Travel grants are available to help students attend any of these meetings.
Applications to the BSR Secretary supported by a letter from supervisor.

DATE	PLACE	DETAILS
10-14/7/95	Sheffield, UK	5th International Conference on Electro-Rheological Fluids, Magneto-Rheological Suspensions and Associated Technology. Contact: Norma Parkes, Dept of Mech. & Process Eng., University of Sheffield, P.O. Box 600, Mappin St., Sheffield, S1 4DU. Tel: 0114 282 5434 Fax: 0114 275 3671 Email: N.Parkes@Sheffield.ac.uk
23-28/7/95	Yellowstone, MT, USA	9th Int.Cong.Biorheology - 2nd Int.Conf.on Clinical Haemorheology, Contact: Prof Giles Cokelet, Dept Biophysics, University Rochester, Rochester, NY 14642, USA Tel: 1-716-275-5283, Fax: 1-716-275-6007
14-18/8/95	Moscow, Russia	International Symposium on 'Advances in Structured and Heterogeneous Continua II. Contact: Prof D.A.Siginer, Dept of Mech Eng., Auburn University, 201 Ross Hall, Auburn, AL 36849-5341, USA Tel: 1-334-844-3331 Fax: 1-334-844-3307
3-6/9/95	Aberystwyth, Wales	'Polymer Melt Rheology', Contact: Prof K.Thomas, Dept.of Mathematics, University of Wales, Penglais, Aberystwyth, SY23 3BZ Tel: 01970-622768 Fax: 01970-622777
6-8/9/95	Leeds, UK	Physical Aspects of Polymer Science - Biennial Meeting of the Polymer Physics Group of the Institute of Physics Contact: Prof G.R.Davies, IRC in Polymer Science & Technology, University of Leeds. Tel: 0113 233 3815 Fax: 0113 233 3846
6-8/9/95	Paris, France	'Gels', Contact: Dr J.W.Goodwin, School of Chemistry, University of Bristol, Cantocks Close, Bristol, BS8 1TS
13-15/9/95	Bordeaux, France	'Recent Developments in Rheology.' 30th Annual Meeting of the Groupe Français de Rheologie, organised in collaboration with the British Society of Rheology. Contact: Secretariat of the 30th Meeting of GFR MASTER - ENSCPB, Université Bordeaux 1, 351 Cours de Liberation, 33405 Talence CEDEX, FRANCE. Tel: (33) 56 84 66 88 Fax: (33) 56 84 66 68
19-22/9/95	Leeds, UK	'First European Coating Symposium', Contact: Dept of Chemical Engineering, University of Leeds, LS2 9JT

DATE	PLACE	DETAILS
12/10/95	London, UK	'The Glassy State in Foods'. SCI Food Eng. Group & Inst. of Food Technologists. Contact: Prof R.Jowitt. Tel: 0171-333 4487 Fax: 0171-937 7783
8-12/10/1995	Sacramento, CA, USA	'67th Annual Meeting, Society of Rheology.' Contact: Robert Powell, Dept. Chemical Eng. & Materials Science, Univ. of California, Davis, CA 95616, USA Tel: (916) 752-8779; Fax: (916) 752-1031 E-Mail: rlpowell@ucdavis.edu. Through 8/15/95 reached at (703) 306-1371; Fax: (703) 306-0319
12-17/11/95	San Francisco, CA, USA	Symposia on 'Developments in Non-Newtonian Flows III' & 'Electrorheological Flow III'. ASME Int.Mech.Cong. and Exposition, Contact: Prof. Dennis A. Siginer, Dept.Mech.Eng., Auburn Univ., 201 Ross Hall, Auburn, AL 36849-5341, USA Tel: 1 205 8443331 Fax: 1 205 8443307 E-mail: dsiginer@eng.auburn.edu
1995	Caracas, Venezuela	'3rd Caribbean Conf. on Fluid Dynamics', Contact: Dr H.Ramkissoo, University of the West Indies, Dept of Mathematics, St Augustine, Republic of Trinidad and Tobago.
3-5/6/96	Glasgow, Scotland	'Production Methods and Workability of Concrete & 4th Concrete - Scotland Exhibition'. Contact: Carol MacDonald, Technology & Business Centre, University of Paisley, Paisley, PA1 2BE, Scotland Tel: 0141 848 3734 Fax: 0141 848 3739
8/1-22/6/96	Cambridge, UK	6 month Workshop on 'Dynamics in Complex Fluids'. For further details, see page 35
18-23/8/96	Quebec City, Canada	'XIIth International Congress on Rheology', Canadian Rheology Group / Groupe Canadien de Rhéologie, Chairman: Prof. D.DeKee, Dept of Chemical Engineering, University of Sherbrooke, Sherbrooke, Québec, J1K 2R1, Canada Congress Secretary: Dr M. Dumoulin, National Research Council - Canada Industrial Materials Institute, 75, de Mortagne, Boucherville (Québec), Canada, J4B 6Y4 Fax: 1-514-641-5103

Travel grants are available to help students attend any of these meetings.
Applications to the BSR Secretary supported by a letter from supervisor.

DATE	PLACE	DETAILS
9-11/9/96	Aberystwyth, Wales	'4th International Conference on Flow Processes in Composite Materials (FPCM'96)' Contact: Dr R.S.Jones, Dept of Mathematics, University of Wales, Penglais, Aberystwyth, Dyfed, SY23 3BZ, UK Tel & Fax: 01970-622672
16-20/2/1997	Galveston, TX, USA	'68th Annual Meeting of the Society of Rheology.'

COURSE DIARY

DATE	PLACE	DETAILS
30/5-2/6/95	Ross Priory, Scotland	Short Course: 'Theoretical, Experimental and Industrial Aspects of Rheology' , Contact: Dr N.E.Hudson, Dept of Pure & Applied Chemistry, University of Strathclyde, 295 Cathedral St., Glasgow, G1 1XL. Tel: 0141 552 4400 X 2162 Fax: 0141 552 5664 Course sponsored by TA Instruments, Leatherhead, Surrey
4-9/6/95	Mountain Lake, VA, USA	An International Group on Polymer Rheology and Processing Presents a Course on 'The Role of Non-Newtonian Fluid Mechanics in Polymer Processing.' Contact: Prof. Donald G.Baird, Dept of Chemical Eng., Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0211, USA Tel: 703-231-5998 Fax: 703-231-5022
26-30/6/95	Bristol, UK	'Emulsion Polymerisation' Contact: Bristol Colloid Centre, University of Bristol, Bristol, BS8 1TS Tel: 0117 929 8388
7-11/8/95	Minneapolis, USA	'20th Annual Short Course on Rheological Measurements: Applications to Polymers, Suspensions and Processing.' University of Minnesota.. Directed by Christopher W. Macosko. Contact: Susan Burke, Professional Development and Conference Services, University of Minnesota, 204 Nolte Center, 315 Pillsbury Drive S.E., Minneapolis MN 55455-0139, USA Tel: (612) 625-3530, Fax: (612) 626-1632
16-20/10/95	Strasbourg, France	'European School in Colloid Science' Contact: Dept for Continuing Education, University of Bristol, Bristol, BS8 1HH Tel: 0117 928 7122

DATE	PLACE	DETAILS
16-20/10/95	Telford, UK	School of Industrial Rheology - SIR'95 this year offers an optional Starter Day which can be taken on its own or added to the 4 day course. 1 day - 'Back to Basics' SIR'95 Venue: Telford Hotel Golf & Country Club. Contact: Terry Hickey, Camtel Ltd, 5 Carrington House, 37 Upper King St., Royston, Herts, SG8 9AZ. Tel: 01763-244280 Fax: 01763-244298
10/10/95		
17-20/10/95		
13-17/11/95	Univ of Strathclyde, Scotland	One Week Course: 'Engineering Rheology.' Contact: Prof J. Ferguson, Dept of Pure & Applied Chemistry, University of Strathclyde, 295 Cathedral St., Glasgow, G1 1XL. Tel: +44 (0) 141 552 4400 X 2161 Fax: +44 (0) 141 552 5664

SITUATION VACANT

University College, London, Department of Civil and Environmental Engineering and Heriot-Watt University, Edinburgh, Department of Building Engineering and Surveying

Postdoctoral Rheologist for research on fresh concrete

Applications are invited for a 2-year fixed term post commencing in September 1995 to do research on the rheology and behaviour under vibration of fresh concrete. The successful candidate will have a Ph.D. and appropriate experience in rheology and/or cement and concrete. He or she will work mainly on this joint project at University College London, but will also be expected to spend about four months in total at Heriot-Watt University, Edinburgh.

Starting salary will be in the range up to £15566 (plus London weighting of £2134).

Further information can be obtained from either Dr P.L.Domone, Department of Civil and Environmental Engineering, University College London, Gower Street, London, WC1E 6BT or Professor Banfill, Department of Building Engineering and Surveying, Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS.

RECENTLY PUBLISHED BOOKS

Information on recent books is given here for the benefit of members, but the Society cannot answer queries about the availability of particular titles. Place orders for books with publishers through booksellers and agents. The summaries are based on those of the publishers. The editor takes no responsibility for their accuracy.

Introduction to Fluid Mechanics. 1994, James A. Fay, The MIT Press, London. pp626, 300 illustrations, ISBN 0-262-06165-1, £22.95/\$34.50.

The author is Professor Emeritus of Mechanical Engineering at the Massachusetts Institute of Technology. This book claims to provide a clear, mathematically efficient and very complete treatment of fluid mechanics at the advanced undergraduate level. Chapters, each of which includes a bibliography and problems and exercises in real engineering situations, divide the book into the following topics: Fluid Statics, Conservative Mass, Inviscid Flow, Conservation of Momentum, Laminar Viscous Flow, Turbulent Viscous Flow, Conservation of Energy, Flow in Fluid Systems, Dimensional Analysis and Modelling, Irrotational Flow and Compressible Flow.

Slurry Transport and Pipeline Transport. 1993, Edited by C.Shook. Mechanical Engineering Publications Ltd (BHR), England. pp844, ISBN 0-85298-874-5. Price now discounted from £89 to £71.

Prepared from papers subjected to rigorous review, this book represents a data source in industrial slurries that is invaluable to the designer, plant operator and student alike. It studies the improvements made in design and operating procedures, covering: pumps and valves; wear and corrosion; systems analysis and maintenance; instrumentation; coal and ash; snow and ice; three phase flows; pipeline hydraulics - Non-Newtonian flows, mixed flow slurries, and coarse particle flows; slurry preparation.

Progress and Trends in Rheology IV. Proc. 4th European Rheol. Conf. C.Gallegos, A.Guerrero, J.Muñoz & M.Berjano (Eds.) Steinkopff Verlag GmbH & Co. KG, Darmstadt, Germany. 1994. pp720. ISBN 3-7985-1005-9

MEMBERSHIP NEWS

The following applications for membership were approved at the Council meeting on March 2nd, 1995

Mr M. Cassidy,
Dept of Mathematics,
UCW Aberystwyth,
Penglais,
Aberystwyth,
Dyfed, SY23 3BZ
(ftsa D)

Prof A. Gaudin,
BP 65,
38402 St Martin d'Heres,
France

(pesa BCDEFG)

Miss R. Rutgers,
Dept of Chemical Engineering,
University of Cambridge,
Pembroke Street,
Cambridge, CB2 3RA
Dyfed SY23 3BZ
(fetsa DLN)

Miss S.S.M. Smith,
Dept of Mathematics,
UCW Aberystwyth
Penglais,
Aberystwyth,

(fetsa BG)

The following cease to be members under rule 4(d):

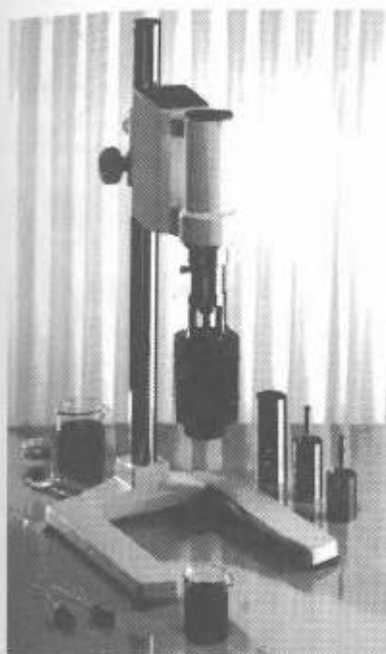
Miss L. Beattie, Mr A.R. Buckley, Mr A.D.J. Butt, Mr I.D. Evans,
Mr B. Houlihan, Dr V. Kukadia, Mr C.J. Lynsdale, Dr S.B. Solbai,
Mr G. Spoors, Miss C.M. Turner

Classification of abbreviations for Members' Rheological Interests

- f Member's main interest is rheology (ie. full-time)
- p rheology is secondary interest (ie. part-time)
- e approach is experimental
- t approach is theoretical
- s area of work is pure science
- a area of work is technology

- | | |
|--------------------------------|-------------------------------|
| A metals | I glasses, ceramics |
| B composites | J oils, greases |
| C solid polymers | K building and road materials |
| D molten or dissolved polymers | L foodstuffs |
| E natural fibres | M biological materials |
| F liquid-liquid systems | N theoretical models |
| G liquid-solid systems | O other systems |
| H particulate systems | |

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