

BULLETIN



BRITISH SOCIETY OF RHEOLOGY

1971, No. 2, Vol. 14

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Hon. Editor:

JOHN HARRIS,
Schools of Chemical Engineering,
The University,
Bradford,
Yorks. U.K.



THE PRESIDENT 1970-72
PROFESSOR J. LAMB

FOREWORD

It seems only a few months ago that we listened to the travellers' tales of those who were fortunate enough to fly half-way round the world to attend the 5th International Congress on Rheology in Kyoto, Japan. Yet in this issue we carry the preliminary notice to the next in the series, the 6th International Congress on Rheology to be held in Lyon, France. No doubt the venue will be popular with those B.S.R. members in Britain who do not have easy access to leviathan expenses accounts, and thus a pilgrimage to one of these events will become a possibility, even perhaps the presentation of a paper and the chance to contribute to the ever expanding set of proceedings which records for posterity the "state of the art," by and large, at that instant in the world's history.

What, of all that will be written down will be remembered in fifty, one hundred or one thousand years' time? We all hope to glimpse a theory or perhaps the experimental results which will last a thousand years, but unfortunately we would not easily recognise work which we are certain would possess that kind of durability. What of the rest? Some of this will no doubt appear briefly only to disappear again without trace, to be drowned in the increasing flood of scientific publications. How much of the work will finish up in this way we do not know, perhaps this unknown factor of durability adds picquancy to the formidable menu which we will no doubt have to consume. Who would want to miss the work which may last a thousand years?

COUNCIL 1970-71

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Hon. Secretary: DR. J. M. STEARNE, ICIANZ Ltd., Victoria 3032.

Hon. Treasurer: DR. E. J. DICKINSON, Australian Road Research Board, Victoria 3101.

Editor (Abstracts): DR. R. FOX, ICIANZ Ltd., Victoria 3032.

Committee: MR. W. H. COPLEY, MR. J. D. GIBSON, MR. K. MARTIN.

SIXTH INTERNATIONAL CONGRESS ON RHEOLOGY

Lyon, France

September 4th-8th, 1972

Under the auspices of The "Comité International de Rhéologie"

Organized by La Fondation Scientifique de Lyon et du Sud-Est

Le Groupe Français de Rhéologie

and

L'Association Rhône-Alpes pour le développement de la Rhéologie

Hon. President: Professor Masao Horio, Kyoto

President of the Organizing Committee: Dr. G. Vallet, Lyon

The "Fondation Scientifique de Lyon et du Sud-Est," the "Groupe Français de Rhéologie" and "L'Association Rhône-Alpes pour le développement de la Rhéologie," invite you to participate at the Sixth International Congress on Rheology which will be held at the University Claude-Bernard LYON I and the National Institute of Applied Science, from Monday, September 4th, to Friday, September 8th, 1972.

Subjects

Papers on the following aspects of rheology will be presented during the congress:

- i. Theory.
- ii. Measuring techniques.
- iii. Test methods.
- iv. Fractures.
- v. Rheologic properties of materials:
 - (a) vapours and gases
 - (b) liquids
 - (c) polymers in the solid state: fibres, films, elastomers and plastics
 - (d) polymers in solution and melts
 - (e) emulsions, suspensions and powders
 - (f) metals and other crystalline materials
 - (g) foods
 - (h) oils and fats
 - (i) cosmetics and drugs
 - (j) paints and printing inks
 - (m) adhesives and lubricants
 - (n) wood and other natural products
 - (o) glass and ceramics
 - (p) concrete and mortars
 - (r) soils and rocks
 - (s) miscellaneous

- vi. Rheo-optic.
- vii. Bio-rheology.
- viii. Miscellaneous.

Languages

It is recommended that papers should be presented in one of the following languages: French, English and German.

Lectures and Communications

The scientific programme of the congress will be composed of general and specialised lectures and contributed papers.

Visits and Ladies Programme

In parallel with the scientific programme, visits will be arranged for the participants and also a daily programme for their wives and guests.

Accommodation

Hotel accommodation and rooms in the university residence will be arranged by the organising committee. Details of price, etc., will be published in the second circular.

Inscriptions and Papers

All who wish to have more complete details of the programme, the papers and participation, are invited to write to the congress secretary before November 1st, 1971.

Persons who wish to present a paper should indicate the category into which it falls principally, according to the subject list on page 6. The presentation of the paper together with discussion time should be about 20 minutes. The title and an abstract of no more than 300 words should be addressed to the organising secretary before March 1st, 1972.

Dr. C. SMADJA,
Boîte Postale n° 1
69 Lyon-Mouche,
France.

RHEOLOGICAL TERMINOLOGY IN FRANCE

Given below are literal translations of the latest batch of definitions of rheological terms proposed by Gpe français de Rhéol. Any comments on the proposals should be sent to M. B. Persoz, G.F.R., 68 Boul. Saint-Michel, Paris 6e, France.

Loi de Hooke généralisée (Generalised Hooke's law)

The law expressing, for infinitely small deformations, the linearity of the relations between the strain tensor ε_{ij} and the stress tensor σ_{ij} of an elastic material.

A material obeying Hooke's law is said to be linear elastic.

Coefficients (ou constantes) élastiques (Elastic constants)

The coefficients of the relations of the generalised Hooke's law.

Modules Élastiques (Elastic moduli)

The coefficients of the relations of Hooke's law determined as the ratio of the six independent components of the stress tensor and expressing them as a function of the six independent components of the strain tensor.

For the most general elastic bodies the set of moduli can be put in the form of a symmetric matrix of order six, corresponding to 21 independent moduli. This number is reduced with the introduction of symmetries in the anisotropy of the body. There are two only for isotropic bodies.

Complaisances élastiques (Elastic compliances)

The coefficient of the relations of Hooke's law resolved with regard to strains (the same remarks apply as for moduli).

Module et complaisance de compressibilité (Bulk modulus or compliance)

For an isotropic solid obeying Hooke's law the modulus K and compliance H appear in the relations

$$\sigma = K\theta \text{ and } \theta = H\sigma$$

relating the mean stress σ (one-third of the trace of the stress tensor) and the cubic dilatation (the trace of the strain tensor). n.b. the coefficient of compressibility used for fluids is identified with the bulk compliance and not the modulus.

Module et complaisance de cisaillement (ou de glissement) (shear modulus and compliance)

For an isotropic solid obeying Hooke's law the modulus G and compliance J appear in the relations between the cartesian components of the deviatoric stresses and the strains.

$$S_{ij} = 2Ge_{ij} \text{ (or } e_{ij} = \frac{1}{2} JS_{ij}); i, j = 1, 2, 3$$

where one has

$$e_{ij} = \varepsilon_{ij} - \frac{\theta}{3} \delta_{ij}; S_{ij} = \sigma_{ij} - \sigma \delta_{ij}; \delta_{ij} = \text{Kronecker symbol.}$$

n.b. Shear modulus is sometimes called Coulomb modulus.

Coefficient de Lamé (Lamé coefficients)

For an isotropic solid the elastic moduli λ and μ appear in Hooke's law resolved with regard to the stresses:

$$\sigma_{ij} = \lambda \theta \delta_{ij} + 2\mu \varepsilon_{ij}$$

(in rectangular axes)

n.b. μ , the second Lamé coefficient is equal to the shear modulus.

Contrainte Uniaxiale (Uniaxial stress)

The state of stress in which two of the three principal stresses are zero.

Module d'Young (Young's modulus)

For a linear elastic solid, whether isotropic or not, subjected to a uniaxial stress, the modulus E appears in the relation:

$$\sigma_{ii} = E \varepsilon_{ii}$$

between the non-zero principal stress and the linear dilatation in the direction of that stress.

n.b. Young's modulus is sometimes called elastic modulus. That term is rejected.

Coefficient de Poisson (Poisson's ratio)

For an isotropic linear elastic solid subjected to a uniaxial stress Poisson's ratio is the opposite of the ratio of the linear dilatation in any direction perpendicular to the non-zero principal stress σ_{ii} , to the linear dilatation in the direction of that stress.

$$\nu = - \frac{\varepsilon_{22}}{\varepsilon_{11}} = - \frac{\varepsilon_{33}}{\varepsilon_{11}} \text{ when } \sigma_{ij} = 0 \text{ unless } i, j = 1$$

Coefficient de viscosité de cisaillement, abbreviated to Viscosité (Viscosity)

For a newtonian fluid the coefficient of viscosity relating a shear stress to the corresponding rate of slip (glissement).

(Here follows an illegible equation)

Coefficient de viscosité de Trouton, abbreviated to Viscosité de Trouton (Trouton viscosity)

The coefficient of viscosity relating a normal component of the stress tensor to the corresponding component of the rate of strain tensor.

Fluide newtonien (Newtonian fluid)

Fluid whose viscosity is newtonian.

Viscosité cinématique (Kinematic viscosity)

The ratio of shear viscosity to density.

Viscosité relative (Relative viscosity)

The relative viscosity of a solution is the ratio of the coefficient of shear viscosity to that of the pure solvent under the same physical conditions.

Viscosité spécifique (specific viscosity)

The specific viscosity of a solution is the quotient of the difference between the shear viscosity of the solution and that of pure solvent, by that of pure solvent under the same physical conditions, according to the relation

$$\eta_{SP} = \frac{\eta - \eta_o}{\eta_o} = \eta_{rel} - 1,$$

where η is the viscosity of the solution and η_o that of the pure solvent under the same conditions.

Viscosité réduite (Reduced viscosity)

The reduced viscosity of a solution is the ratio of the specific viscosity to the concentration of the material in the solution.

$$\eta_{red} = \frac{1}{C} \frac{\eta - \eta_o}{\eta_o} = \frac{1}{C} \eta_{SP}$$

Modifications, approved by the Council, of two definitions which have already been adopted.

32. Fragile (Brittle)

This is said of a solid which breaks without appreciable permanent deformation.

It is said also of the mode of rupture of a solid when the separation of parts of that solid is attained following a small relative displacement of the two edges of the surface of rupture.

35. Durcissement (Hardening)

The elevation of the threshold of plasticity accompanying the production of permanent deformation.

In case of confusion with the hardening arising from other causes one talks of **rhéodurcissement** (work hardening)

D. W. HADLEY.
11: 5: 71.

ROTATIONAL FLOWS OF NON-NEWTONIAN LIQUIDS IN AGITATED VESSELS

May 4th, 1971

SYMPOSIUM

Venue: University of Salford.

Organisers: Institution of Chemical Engineers (North-Western Branch)

Programme

- "Determination of Material Parameters of Viscoelastic Fluids by non-Viscometric Rotational Flows." R. A. Mashelkar and J. Ulbrecht.
- "Non-Newtonian Flows around Rotating Spheres and Discs." D. D. Kale, J. V. Kelkar, R. A. Mashelkar and J. Ulbrecht.
- "Alternative Stable Modes of Flow in Anchor Agitated Systems." J. M. Smith.
- "Dynamics of non-Newtonian Flow in a Vessel Stirred by a Helical Agitator." V. V. Chavan, A. S. Jhaveri and J. Ulbrecht.
- "A Scale-up Procedure for a New Mixer for Paste-like Materials." D. C. -H. Cheng, C. Schofield and D. J. Tookey.
- "Similarity Analysis of non-Newtonian flow in Vessels." P. Schümmer.
- "Preliminary Estimate of Mean Rate of Strain in Rotational Flows of non-Newtonian Liquids in Centrifugal Pumps." C. B. Duckham.

Synopses of Lectures for the above Symposium

1. *Determination of Material Parameters of Viscoelastic Fluids by Non-Viscometric Rotational Flows*, by Dr. R. A. Mashelkar and Dr. J. Ulbrecht (University of Salford).

The utility of a rotating sphere and a disc for the determination of the material parameters of non-Newtonian fluids is examined theoretically. A semi-empirical approach is proposed to calculate the zero shear viscosity of these fluids. Experimental data obtained with a variety of fluids have indicated that both the theoretical and empirical approaches give comparable values of zero shear viscosity. The possibility of the determination of material parameters of a certain class of third order fluids by these rotational non-viscometric flows is confirmed experimentally.

2. *Non-Newtonian Flows around Rotating Spheres and Discs*, by D. D. Kale, J. V. Kelkar, Dr. R. A. Mashelkar and Dr. J. Ulbrecht (University of Salford).

The possibility of utilising the non-viscometric rotational flow around simple geometrical bodies (which are amenable to analytical

solutions) to simulate the complex flow behaviour around agitators is examined. The measurements of the torque and the r.p.m. for spheres and discs rotating in viscoinelastic and viscoelastic liquids are carried out. The dimensionless correlations based on the above data confirm the fact that such approaches could be successfully used for simulating the flow phenomena around agitators.

3. *Alternative Flow Regimes in Anchor Agitated Vessels*, by Professor J. M. Smith (Delft).

Flows in vessels with anchor shaped agitators have been investigated. The paper will discuss alternative flow patterns which can be stable, and factors which decide stability. Flow visualisations have been carried out using closed circuit television.

4. *Dynamics of a Non-Newtonian Flow in a Vessel Stirred by a Helical Agitator*, by V. V. Chavan, Dr. A. S. Jhaveri and Dr. J. Ulbrecht (University of Salford).

The dynamics of mixing of Newtonian and inelastic non-Newtonian fluids agitated by helical screw impellers with and without draft tube was studied. The important variables appearing in the power correlation were found by performing a similarity analysis. After some simplifying assumptions it was possible to propose correlations which accounted for all the important geometrical variables. For a helical screw with draft tube the correlation was mainly based on a model behaviour proposed in this work. The experimental data obtained in this work and those available in the literature confirmed the validity of these correlations.

5. *A Scale-up Procedure for a New Mixer for Paste-like Materials*, by Dr. D. C. -H. Cheng, C. Schofield and D. J. Tookey (Warren Spring Laboratory).

This paper describes the design of a new type of mixer intended for highly viscous fluids and heavy paste-like materials. It consists of a pair of rotors of a special shape such that, when in contra-rotation, the tip of one or other of the rotor is always in contact with the opposite rotor and with the walls of the mixing chamber. The mixing action is obtained by squeezing the material between the spaces between the rotors and expelling it through small clearances between the rotors. The material to be thus mixed is gathered from the walls of the chamber and from the surfaces of the rotors by the tips mentioned, which action also serves to clean the mixer. The high pressure generated in the mixing spaces are used for self-emptying to discharge the material after mixing. Both batch and continuous forms of the mixer are possible.

A pilot scale batch mixer with a capacity of 4.5 kg. has been constructed and used to study the action when blending butter. With a 50% loading, it was found that the power requirement per unit

weight of butter was the same as that obtained in conventional Z-blade blenders, but in the new mixer the blending was complete in 2 to 3 minutes instead of 15 to 20 minutes in the Z-blade blender.

A theoretical study of the mixing action has been carried out and has led to the derivation of scale-up rules that allow the power requirement and mixing time data obtained on the pilot scale mixer to be scaled up in the design of full-scale production equipment.

6. *Similarity Analysis of Non-Newtonian Flow in Vessels*, by Dr. P. Schümmer (University of Aachen).

The very complex movement of fluids in mixing vessels does not normally allow an analytical solution of the problem. It is therefore necessary to use empirical methods. A rational computation of the results, however, is only feasible with an extended similarity analysis. For viscoelastic fluids it is possible to define 3 classes of dimensionless groups:

1. groups consisting of purely geometrical parameters
2. groups consisting of the relevant rheological material properties
3. groups consisting of the remaining parameters, one characteristic length and two characteristic rheological parameters.

In experiments with the same rheological fluid and with similarity in geometry, only the groups of class 3 may vary.

Further simplification in the description of mixing systems is often possible by variation of one material parameter depending on the mode of operation; for instance one may replace the zero-viscosity in the Reynolds number by an apparent (variable) viscosity.

7. *Preliminary Estimate of Mean Rate of Strain in Rotational Flows of Non-Newtonian Liquids in Centrifugal Pumps*, by C. B. Duckham (University of Salford).

Local rates of strain are almost impossible to estimate from existing knowledge of flow patterns in centrifugal pumps. By fitting a dynamometer to a single-stage end-suction pump with semi open impeller, the apparent in-pump viscosity of a pseudoplastic fluid can be measured, and from it an estimate made of mean rate of strain.

NOTICE

Heat Transfer at Low Reynolds Number

A copy of the above report by John E. Porter has been made available by the Institution of Chemical Engineers. This 30-page report with 242 references deals with heat transfer to highly viscous liquids in laminar flow. The survey presents some recommendations for design equations and suggests future investigations to clarify some of the existing problems.

The copy may be borrowed by any member of the B.S.R. by applying to:

Dr. D. W. HADLEY,
J. J. Thomson Physical Laboratory,
Whiteknights,
Reading RG6 2AF.

B.S.R. AUTUMN CONFERENCE 1971

Exeter University, September 20th-23rd, 1971

List of papers on May 31st, 1971

1. *The viscoelastic properties of tin printing inks.* G. A. Lewis and A. J. B. Spaul, Dept. of Chemistry, Brunel University.
2. *Mechanical properties of cellular polyurethanes used in the footwear industry.* R. E. Whittaker, S.A.T.R.A., Kettering.
3. *Secondary flows about a sphere and a disc rotating in an elastico-viscous liquid contained in a large tank.* E. K. Cairncross and G. S. Hansford, Dept. of Chemical Engineering, University of Capetown, Rondebosch.
4. *Stress relaxation in regenerated cellulose at low temperatures.* P. M. Haughton and D. B. Sellen, Astbury Dept. of Biophysics, University of Leeds.
5. *Effect of changes of surface tension and contact angles on normal force measurement with the Weissenberg Rheogoniometer.* J. F. Hutton, Thornton Research Centre, Chester.
6. *Interpretation of experimental results from a new rheometer.* J. M. Broadbent and K. Walters, University College of Wales, Aberystwyth.
7. *Dynamic mechanical properties of polyethylene melts determined by a balance rheometer. Effects of molecular weight, molecular weight distribution and branching on the viscoelastic behaviour in the linear and non-linear fields.* F. Assioma and A. Kepes, Research Centre, Ethylene-Plastique, Mazingarbe, France.
8. *A new torque and normal thrust measuring system for the Weissenberg rheogoniometer.* R. W. Higman, Warren Spring Laboratory, Stevenage.
9. *New developments in parallel plate rheometry for the study of pastes.* D. C. -H. Cheng and K. G. Laws, Warren Spring Laboratory, Stevenage.
10. *Some new developments in the study of thixotropic behaviour.* D. C. -H. Cheng, Warren Spring Laboratory, Stevenage.
11. *Simple stretching experiments on fluids.* R. Bragg, Dept. of Chemical Engineering, Birmingham University.

12. *Viscosity—concentration relations in deflocculated kaolin suspensions.* K. M. Beazley, English Clays, Lovering, Pochin & Co. Ltd., St. Austell.
13. *The anisotropy of creep behaviour in oriented thermoplastics.* D. W. Saunders and M. W. Darlington, Cranfield Institute of Technology.
14. *A rotational surface viscometer.* L. A. Adorjan, Dept. of Minerals Engineering, Birmingham University.
15. *Amplitude and phase profiles in oscillatory tube flow.* R. Maheshwari and J. Harris, Dept. of Chemical Engineering, Bradford University.

Joint Spring Conference 1972

RHEOLOGY OF LUBRICANTS

Preliminary arrangements have been made for a joint Institute of Petroleum/Institution of Mechanical Engineers/British Society of Rheology meeting in early July, 1972. The suggested venue for a two-day meeting was either Oxford or Nottingham University. An open reception would be held during the evening prior to the meeting and there would be a Conference Dinner on the first evening.

The main session headings suggested are:

1. The Rheology of Petroleum-based Lubricants.
2. The Rheology of Synthetic Lubricants.
3. The Rheology of Greases.
4. Non-Conventional Lubricants.
5. New Concepts in Theoretical and Experimental Rheology.
6. Research Reports.

Papers are invited for the above meeting and abstracts of about 200 words may be sent to:

Professor D. DOWSON,
Dept. of Mechanical Engineering,
The University,
Leeds, U.K.

or

Dr. J. HARRIS,
School of Chemical Engineering,
The University,
Bradford, U.K.

PROFESSOR MOORE MEMORIAL LECTURE

The second Professor Moore Memorial Lecture will be held at the University of Bradford on Thursday, October 21st, 1971, at 6.30 p.m., when Sir Harry W. Melville will speak on the subject of

Elastomers

Light refreshments (free of charge) at 6 p.m., and a buffet supper (at a cost, including wine, of 82½p) immediately following the lecture, will be available.

Attendance at the lecture will be by ticket only, for which applications should be made by letter to The Registrar, University of Bradford, Yorkshire, BD7 1DP, before Friday, October 8th, 1971. Applications should state clearly whether tickets are required for the lecture only (which will include the preceding light refreshments) or for the lecture and the buffet supper. If the latter is required, a remittance of 82½p, payable to the University of Bradford, should accompany the application.

UNIVERSITY OF BRADFORD

Bradford, Yorkshire, BD7 1DP, Telephone 0274 33466

Postgraduate School of Studies in Polymer Science

Residential post-experience course

Molecular Weight Determination of Polymers

20-24th September, 1971

Acting Chairman and Senior Lecturer in Polymer Science,
Dr. R. P. Sheldon

Course Organiser: Dr. R. J. Fort.

Course Tutors:

Dr. R. J. Fort (University of Bradford)
Dr. A. F. Johnson (University of Bradford)
Mr. G. P. Pearson (University of Bradford)
Dr. R. P. Sheldon (University of Bradford)
Dr. B. M. Tidswell (University of Bradford)
Mr. T. J. Bowen (University of Leeds)

PLASTICS IN MEDICINE AND SURGERY
University of Newcastle-upon-Tyne Medical School

SYMPOSIUM

Plastics Institute—North Eastern Section

September 15th and 16th, 1971

Physics Building,
University of Newcastle-upon-Tyne

DIARY

1971

29 August–2 September. Symposium—Two-Phase Systems at Technicon City, Haifa, Israel.

16–23 September. Exhibition—6th International Plastics Trade Fair “K–71” at Dusseldorf.

20–23 September. Conference—Annual B.S.R. Autumn Conference, Exeter University.

21–23 September. Conference—Modern Developments in Flow Measurement Joint A.E.R.E./N.E.I. at A.E.R.E. Harwell.

2 & 3 November. Conference—Plastics in Fire at Inst. Elec. Engrs., London, by Plastics Institute.

1972

July. Conference—Rheology of Lubricants Joint Inst. Pet./I.Mech.E./B.S.R. at Oxford/Nottingham University (venue to be decided).

4–8 September. Congress—6th International Congress on Rheology, Lyon, France.

BRITISH SOCIETY OF RHEOLOGY

Computer Program Catalogue

Publication Abstract

1. Author
1. Establishment
- Tel. No.....
3. Program Abstract
- Input Data
- Output Data
4. Program date
5. Language
6. Computer requirements
7. Type of Input/Output
8. References
9. Related programs
10. Available for copy/data processing

Return to: Dr. J. Harris,
Postgraduate School of Chemical
Engineering,
University of Bradford,
Bradford 7, U.K.

Additional blank abstract sheets are available as required from the above address.