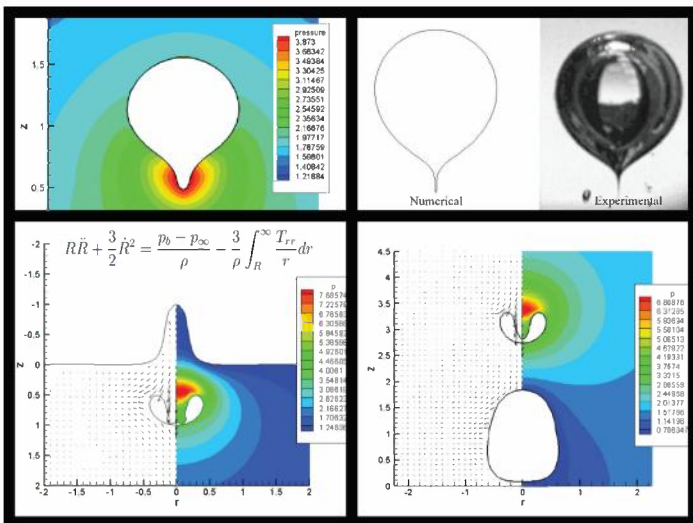


THE BRITISH SOCIETY OF RHEOLOGY

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THE BRITISH SOCIETY OF RHEOLOGY

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THE BRITISH SOCIETY OF RHEOLOGY



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EDITORIAL

Welcome to Volume 54 (issue #3) of the British Society of Rheology Bulletin. The lead article in this issue is provided by the BSR Annual Award winner for 2012, Prof. Tim Phillips, as is the cover illustration (details below). My attempt to scan the archive of Bulletins also continues and some interesting club notes have been included from issues #2 and #3 (1941) for you to enjoy. Hopefully at some point all of the past issues will be made available on the website (currently available from 1997, Vol 40, No 4 onwards).

Rob Poole, Liverpool November 2013.

SUBMISSIONS TO THE BULLETIN

Submissions to the Bulletin are welcomed. Electronic submissions by email to the Editor (bulletin@bsr.org.uk) are preferred in word format (e.g. .doc or .docx). Please always provide a contact name, address, e-mail, or telephone number in case of problems. The deadline for submission is Feb. 15th, June 15th and Oct. 15th, respectively, for three issues annually.

COVER ILLUSTRATION

The cover image supports the article by Prof. Tim Phillips and shows various bubble rise and bubble collapse phenomena:

Top left: Bubble collapse near a rigid wall in a Maxwell fluid ($De=5$, $Re=0.2$, Stand-off distance $h=1.1$)

Top right: A rising bubble in a Maxwell fluid ($De=0.9$, $Re=1.2$) and experimental comparison

Bottom left: Bubble collapse near a free surface in a Maxwell fluid ($De=2.5$, $Re=1.0$, $h=0.5$)

Bottom right: Two bubble collapse near a rigid wall in a Newtonian fluid ($Re=\infty$, $h_1 = 1.0$, $h_2 = 3.6$)

where De = Deborah number and Re = Reynolds number. Thanks to Dr. Steven Lind (Manchester Metropolitan University) for generating these images.

AIMS OF THE SOCIETY

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

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

If your work is concerned with rheology in any way, then you have much to gain by joining the British Society of Rheology, including

- advance your knowledge by attending our conferences
- receive publications including Rheology Abstracts, Bulletin and Rheology Reviews
- learn of current instrumentation and accessories plus new developments.
- access to non-Newtonian Club linking industry and academia
- travel Grants, Poster Prizes, Career Opportunities
- network with fellow members who, while working in a different discipline or industry, may be facing similar problems to yours

The Society is non-profit making and is registered as a charity. For the details, you are warmly welcome to visit our web site <http://www.bsr.org.uk/>, and to apply for membership on-line.

Bubble Dynamics – Curse to Cure

Tim Phillips

Bubble dynamics and cavitation in Newtonian fluids has been studied for a round a century. One of the first studies of cavitation damage was commissioned by the British Admiralty who wished to determine the cause of damage to ship propellers – damage to the blades was thought to be caused by collapsing cavitation bubbles. Although damage to solid surfaces in the near vicinity of collapsing bubbles has been the most intensively studied consequence of cavitation, other widely known effects include reduced hydraulic performance and the generation of excessive vibration and noise.

Apart from hydraulics and turbomachinery, an understanding of cavitation phenomena is important in areas of science and engineering such as acoustics, biomedicine, botany and sonochemistry. They occur in numerous industrial processes such as cleaning, lubrication, printing and coating. They are also used in many biomedical applications such as ultrasound and shockwave lithotripsy procedures.

A major focus in cavitation research has involved the study of bubble dynamics due to the relationship between a collapsing bubble and instances of damage to solid surfaces in its near vicinity. The first theoretical study of cavitation was performed by Lord Rayleigh who considered the collapse of a single spherical void in an infinite bath of incompressible fluid [1]. An important conclusion of this study was that cavitation damage was caused by the extremely large pressure generated as the bubble collapses. The experimental work of Benjamin and Ellis almost 50 years later showed that other complex mechanisms may also play a role in cavitation damage [2]. In particular, the high speed jet that forms during asymmetric bubble collapse can penetrate and thread the bubble and impact on the wall. A thorough review of the dynamics of cavitation bubbles can be found in the review article of Brujan and Williams [3].

Spherical Bubble Dynamics

The dynamics of spherical cavitation bubbles is not relevant to the problem of cavitation erosion since bubbles that are close enough to a rigid

boundary to cause damage will always collapse aspherically. However, the problem is of interest since it can be used to compare experimental results with theoretical predictions.

A convenient experimental technique for creating a single bubble in a liquid is to focus a short pulse of laser light into the liquid [3]. Depending on the focal spot size, the transverse mode structure of the laser, the pulse duration, and the light intensity a small or several small volumes of liquid are rapidly heated depending on the laser and the pulse width employed.

The large pressure in the laser-induced vapour bubble leads to a very rapid growth in bubble volume that overshoots the equilibrium state, in which the internal bubble pressure equals the hydrostatic pressure. The increasing difference between the hydrostatic pressure and the falling internal bubble pressure then decelerates the expansion finally bringing this expansion phase to a conclusion. In the next phase, the expanded bubble collapses again due to the static background fluid pressure. The collapse compresses the bubble content into a very small volume, thus generating a very high pressure that can exceed 1 GPa for an approximately spherical bubble collapse. The rebound of the compressed bubble interior leads to the emission of a strong pressure transient into the surrounding liquid that can evolve into a shock wave.

An extensive set of experiments to investigate the behaviour of laser-generated bubbles in shear-thinning elastic fluids (0.5% aqueous solutions of CMC and PAM) have been performed by Brujan [4]. The interesting observation was that initial bubble size matters, for bubbles with $R_{\max} > 0.5$ mm polymer additives did not affect the bubble motion in any significant way, and the duration of the oscillation time is equal to the Rayleigh time. However, for bubbles for which $R_{\max} < 0.5$ mm a prolongation of the oscillation time was observed, which increases with decreasing maximum bubble radius.

The simplest mathematical model for predicting bubble dynamics is the Rayleigh-Plesset equation. This model is restricted to the study of spherical dynamics. It was derived for an inviscid fluid by Lord Rayleigh while Plesset included viscous effects. Let $R(t)$ be the radius of the bubble. Then writing the Navier-Stokes equations in spherical polar coordinates one can show that under the assumption of zero mass transfer across the bubble surface the radial velocity is given by

$$u(r, t) = \frac{R^2 \dot{R}}{r^2} \quad (1)$$

If we substitute (1) into the radial component of the momentum equation and integrate we obtain

$$\frac{2R\dot{R}^2 + R^2 \ddot{R}}{r} - \frac{R^4 \dot{R}^2}{2r^4} = \frac{p - p_\infty}{\rho} \quad (2)$$

where $p \rightarrow p_\infty$ as $r \rightarrow \infty$. In the absence of surface tension and mass transfer across the bubble, the pressure at the bubble surface is given by

$$p = p_b + 4\mu \frac{\dot{R}}{R} \quad (3)$$

from which we derive the Rayleigh-Plesset equation

$$R \ddot{R} + \frac{3}{2} \dot{R}^2 + 4\mu \frac{\dot{R}}{R} = \frac{p - p_\infty}{\rho} \quad (4)$$

This equation may be integrated to obtain the collapse time for a spherical cavity in an inviscid incompressible liquid.

The model can be extended to investigate bubble dynamics in viscoelastic liquids using, for example, the Oldroyd model. The dynamics predicted are very different to the Newtonian case. The principal difference is that the model predicts a damped oscillation of $R(t)$. Of course, the Rayleigh-Plesset equation is restrictive since it only applies to spherical dynamics.

Boundary Element Method

The boundary element method has been used with considerable success to study the behaviour of bubble dynamics near rigid and free surfaces, for example [5]. The method is able to predict the formation of a liquid jet and, for Newtonian fluids, has been shown to be in agreement with experimental predictions. Under the assumptions of incompressibility and irrotationality, the conservation of mass implies the existence of a velocity potential which satisfies Laplace's equation in a region exterior to the bubble. Green's theorem enables the solution to be written in terms of an integral over the boundary $\partial\Omega$ of the bubble

$$c(\mathbf{p})\varphi(\mathbf{p}) = \int_{\partial\Omega} \left(\frac{\partial\varphi}{\partial n}(\mathbf{q})G(\mathbf{p}, \mathbf{q}) - \varphi(\mathbf{q})\frac{\partial G}{\partial n}(\mathbf{p}, \mathbf{q}) \right) dS \quad (5)$$

where $c(\mathbf{p})=2\pi$ if $\mathbf{p} \in \partial\Omega$ and

In 3D the Green's function is given by

$$G(\mathbf{p}, \mathbf{q}) = \frac{1}{|\mathbf{p} - \mathbf{q}|}. \quad (6)$$

Provided that the extra-stress tensor can be expressed as the gradient of some scalar function ψ we can derive a generalised Bernoulli equation of the form

$$\nabla \left(\rho \frac{\partial\varphi}{\partial t} + \frac{\rho}{2} |\nabla\varphi|^2 + p - \psi \right) = C(t) \quad (7)$$

where p is the pressure and ρ is the density. This last equation is derived by integrating the mathematical statement of the conservation of linear momentum.

We must ask the very important question: for which constitutive equations and for what type of flows guarantees the existence of scalar function ψ satisfying

$$\nabla \cdot \mathbf{T} = \nabla\psi \quad (8)$$

Generalized Bernoulli equations are admissible for inviscid and viscous Newtonian fluids, linear Maxwell and Jeffrey fluids for general irrotational flows. However, there is an incompatibility in the theory of viscoelastic potential flow which means that

$$\nabla \times \nabla \cdot \mathbf{T} \neq 0 \quad (9)$$

There are general constitutive equations for which this equation is not satisfied even for general irrotational flows. However, the spherical bubble collapse is one example of a purely extensional motion for which the equation of motion is satisfied.

Assuming that $\phi, \psi \rightarrow \infty$ at infinity and relating the fluid pressure on the surface of the bubble to the pressure inside the bubble using a balance of normal forces we can obtain a dynamic condition on the bubble surface of the form

$$\rho \frac{D\varphi}{Dt} = \frac{\rho}{2} |\nabla\varphi|^2 + \psi - T_{nn} + p_\infty - p_b \quad (10)$$

For an inviscid Newtonian fluid $T_{nn} = 0$ whereas for a viscoelastic fluid T_{nn} is determined from the normal component of the constitutive equation. Surface tension can be easily accommodated in the model by modifying this dynamic condition.

The solution procedure involves solving (7) to update φ , then solving the boundary integral equation (2) to determine the normal derivative of φ . Finally, the bubble surface is updated by solving

$$\frac{Dx}{Dt} = \nabla\varphi. \quad (11)$$

Although the bulk effects are missing from this model, it does provide some insight into the interaction between the bubble and fluid. The model has been shown to provide qualitative agreement with experimental observations. It has also been shown to provide quantitative agreement with some experiments such as a bubble rising in a viscoelastic liquid (see top right figure on front cover).

Multi-phase Flows

However, it is clear that a more sophisticated model is necessary to quantitatively predict the evolution of bubble growth and collapse in viscoelastic fluids since the admissibility condition is only satisfied in an approximate sense for moderate to large Reynolds numbers. The most complete model for bubble dynamics requires the solution of a multiphase problem. In this statement of the problem we need to solve the full governing set of partial differential equations comprising the conservation equations and the constitutive equation in each phase with appropriate conditions across the bubble surface. This is a much more computationally demanding problem than the boundary element approach described above. One such approach for solving the complete problem is based on a marker particle method and has been described in a couple of recent papers [6,7]. The basic idea is to use a single phase description of the problem and allow the material parameters such as viscosity and density to vary across the phases by identifying a phase with each marker particle.

Everything that we have described so far relates to a single bubble. Multiple bubbles can be accommodated through the marker particle method. However, the dynamics of a large number of particles will be computationally expensive and other more efficient techniques will need to be developed for solving problems involving tens and hundreds of bubbles.

Biomedical Applications

We conclude this short article by describing some of the more recent application of bubble dynamics to biomedical problems. One such application is a procedure known as sonoporation. This is a method for delivering genes into cells using ultrasound to cause transient membrane permeabilisation. The likely cause of this mechanism is widely thought to be the interaction of cavitation bubbles with the cells. The collapse of these cavitation bubbles creates shock waves that can permeate a cell allowing the uptake of large molecules such as DNA. However, the procedure needs to be handled with care and precision this cavitation activity must be controlled as it may also cause cell death on a single cell level, as well as microvascular haemorrhage and disruption of tissue structure.

Shock wave lithotripsy (SWL) is a non-invasive medical procedure that uses focused shock waves to fragment kidney stones. The patient is usually placed in a tub of water and a shockwave is created which is then focused on the stone which fragments it. Most kidney stones are made of calcium oxalate and calcium phosphate and they usually form when these substances, which are dissolved in urine, solidify. They can be passed naturally by the body if they are small enough but if they are too large they must be removed. Current generators use either electro-hydraulic (uses electrodes, waves are focused using reflector), piezoelectric (uses an array of spherically aligned piezoelectric elements) or electromagnetic (acoustic pulses are focused using a paraboloid reflector) elements to produce energy which is directed onto the stone under X-Ray or ultrasonic guidance. In a typical procedure, several hundreds to thousands of shock waves are fired at a rate of roughly 0.5Hz. These shock waves have an initial short compressive peak followed by a longer rarefaction which can induce cavitation. As kidney stones are typically immersed in urine, the tension leads to the formation of nuclei sites near the stone.

Two mechanisms are then important in stone comminution: shock wave propagation within and around the stone and cavitation erosion due to violent bubble collapse along the surface. For collapsing bubbles near a boundary, an asymmetry in the flow field is created which causes non-spherical deformation and jetting towards the surface. In the case of SWL, the jetting of nearby bubbles is caused by the propagating shock waves as well as the presence of rigid boundaries.

The use of laser light to achieve controlled and confined thermal damage in tumour tissue has produced a revolution in cancer therapy. However, the biggest disadvantage of this treatment is its non-selectivity since both normal and tumour cells in the path of the laser light are damaged. This drawback has been overcome by employing photothermal agents to achieve selective heating local to tumours giving rise to a treatment known as photothermal therapy. The therapy requires considerably less laser energy to damage the diseased cells which means the process is less invasive.

It was recently found that laser-induced local heating of cellular structures mediated by light-absorbing nanoparticles may provide localized damage that can be limited to single cells in a procedure known as plasmonic photothermal therapy. The key idea in this therapy is that nanoparticles locally convert optical energy into thermal energy through their unique mechanism of plasmon resonance. A spherical nanoparticle, with a diameter much smaller than the wavelength of light, irradiated with an electromagnetic field at a certain frequency induces a resonant oscillation of the medium free electrons across the nanoparticle. The resonance lies at visible frequencies for the noble metals such as gold and silver. The primary photothermal effect of laser-nanoparticle interaction is the thermalization of nanoparticles while secondary effects include the heating of surrounding media due to thermal diffusion and the generation of cavitation nanobubbles if the temperature of the media exceeds the evaporation threshold. This sudden formation of cavitation nanobubbles causes mechanical stress on the cells which ultimately leads to cell destruction. The influence of the non-Newtonian properties of intracellular fluid on the dynamics of cavitation bubbles generated during plasmonic photothermal therapy has never been investigated and remains an open problem.

These are just a sample of the many problems that arise in biomedicine concerning the dynamics of bubbles. A deeper understanding of the

mechanisms at play will undoubtedly have important consequences for the treatment and cure of many health-related conditions and provide researchers with a plethora of interesting problems for years to come.

Acknowledgements. I have enjoyed the collaboration with a past (Steve Lind – Manchester Metropolitan University) and present (Mike Walters) PhD students on this work and I would like to take the opportunity to acknowledge this.

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"From the Archives"

BULLETIN OF THE

BRITISH RHEOLOGISTS' CLUB

Address for communications: c/o The Institute of Physics,
at The University,
Reading, Berks.

NO.2

JUNE 1941

Issued (gratis) to
members of the Club
only.

CLUB NOTES

Suggestions.

The committee takes this opportunity of thanking members who have expressed their appreciation of the club and have contributed suggestions and criticisms. These are always gratefully received and given careful consideration.

American Co-operation.

We are glad to note an appreciative paragraph about the club in the November (1940) number of the "Rheology Leaflet" of the American Society of Rheology. Co-operation with our American colleagues is most welcome and we hope to keep in close touch with them especially when the very difficult and controversial questions of nomenclature and definition are being discussed.

Public Interest in Rheology.

It is significant that "John O' London's Weekly" should devote a whole page to an article by J. Harley-Mason entitled "Rheology - A New Science". Many club members would wish they knew as much about thixotropy as the author would have us believe is in fact known. This growing appreciation of the existence of Rheology as a Science is to be applauded and the appreciation of its importance in industry is, it will be remembered, one of the objects of our club. Next time you are asked by a layman "what is Rheology" you can escape an involved discussion, if you will, by suggesting the purchase of a copy of "John O' London's Weekly" for 9th May, 1941.

Editor's note: I am attempting to track down the John O'London's Weekly from the 9th May 1941 and hope to report back in a future issue.

Address for communications: c/o The Institute of Physics,
at The University,
Reading. Berks.

NO. 3

OCTOBER 1941

Issued (gratis) to
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only.

CLUB NOTESMembership.

The membership of the Club is now 95. This is most satisfactory for a year's run in wartime. Members have expressed an interest in a very wide range of materials. The principal of these may be classified as follows, the numbers in brackets indicating the number of interested members: Blood (2), Cellulose and paper (5), Ceramics and clays (9), Dairy products and margarine (7), Emulsions (6), Flour and doughs (3), Foodstuffs (general) (6), Glass (2), Glue and adhesives (5), Ink (7), Metals (5), Muscle (3), Oils and greases (12), Paints and similar materials (13), Pastes (3), Photographic materials (3), Plastics and resins (8), Rubber (7), Soils, silts and sediments (2), Starch (1), Tars, bitumens, road materials, etc. (13). It will be observed that some are interested in several of these categories, but others who have expressed interest in methods rather than materials do not appear in the classification.

Encouragement from abroad.

Dr. M. Rolner, whose work on mathematical rheology will be well-known to members of the Club, has sent us the following from Jerusalem: "I have told all disheartened people the story of how the British Rheologists' Club had a meeting in London on February 22nd, which had an 'excellent attendance'. I have just started a course of lectures on theoretical Rheology at the Physics department of the Hebrew University. At the last lecture I read them your letter. Please tell the British Rheologists' Club that our thoughts are with them. This is a message from the audience to my lectures and from me."

BSR Student Travel Awards

The 301st Council Meeting established the principle that student travel grants have the objective of encouraging students to disseminate their research. Applicants for a student travel bursary must normally have been a member of the Society for 9 months, may be working worldwide and presenting research at a conference, by paper or poster. The grant will be made on receipt of a report on the event.

The British Society of Rheology wishes to establish a transparent mechanism for the award of travel bursaries and to solicit applications from its student membership. Travel bursaries are available to student members of the Society to present their research at a conference that contains a strong rheological element, in situations where no other sources of funding are available to cover the whole cost of the meeting. Suitable conferences include the International Congress of Rheology, the Annual European Rheology Conference and conferences organized by the Society.

The next closing date for consideration of the award of a travel bursary is Thursday 27th February 2014 with successful applicants notified by the beginning of April. Applicants should include in their submission the name and location of the conference, the title, authors and abstract of the paper submitted to the conference, a breakdown of the projected costs of attending the meeting and a supporting letter from their research supervisor. The support of the British Society of Rheology should be mentioned in the conference presentation. The Society's logo may be used for this purpose. Payment of the bursary will be made on receipt of a report on the conference. The conference report will be published in the Bulletin of the Society.

Applications for a travel bursary should be sent to the Secretary (secretary@bsr.org.uk).

Simon Cox
BSR Honorary Secretary



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INSTITUTE OF NON-NEWTONIAN FLUID MECHANICS

Lake Vyrnwy Hotel, Wales U.K.

APRIL 14 - 16, 2014



Programme

The meeting will commence at 12 noon on Monday 14th April 2014 and finish at lunchtime on Wednesday 16th April 2014.

A principal focus of the meeting will be advances in *rheometry* (theory, experimentation and instrumentation) but papers on *general rheology* are also welcome.

Festschrift

Papers presented at the meeting will be considered for publication in a *Festschrift* Special Issue of the *Journal of Non-Newtonian Fluid Mechanics*. This *Festschrift* will be dedicated to Professor K Walters FRS on the occasion of his 80th birthday and in recognition of his contributions to rheology.

Additional Information and contact details.

Further information will be posted on the website from time to time. Any queries should be directed to:

Rhodri Williams (P.R.Williams@swansea.ac.uk)

or Peter Townsend (p.townsend@swansea.ac.uk)



The British Society of Rheology

Midwinter Meeting 2013

"Coating, Printing and Painting"

December 16th & 17th, 2013

Institute for Manufacturing

University of Cambridge

This meeting aims to provide an overview of current research in rheology particularly in its application to printing, painting and coatings, for example in contact and inkjet printing, and spray painting.

Keynote Speakers

Prof Detlef Lohse (University of Twente)

Dr Philip Threlfall-Holmes (AkzoNobel)

Prof Rhodri Williams (Swansea University)

Organising committee:

- **Oliver Harlen** (University of Leeds)
o.g.harlen@leeds.ac.uk
- **Ian Hutchings** (University of Cambridge)

Website: <http://www.bsr.org.uk/meetings.asp>

Meeting Contact: Alice Cozens
Inkjet Research Centre Administrator
Institute for Manufacturing
University of Cambridge
17 Charles Babbage Road
Cambridge CB3 0FS

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BSR membership news

New Members

Jamie Fletcher

Maria Marlow (University of Nottingham)

Susanne Patel (University of Leeds)

Galina Pavlovskaya (University of Nottingham)

Ashwin Bharadwaj (University of Illinois)

Kathryn Skilling (University of Nottingham)

One year's free membership is offered to participants of BSR meetings who are not already members. The following accepted the offer of membership for 2013 following the BSR Midwinter Meeting at Aberystwyth in December 2012:

Adil Mughal (Aberystwyth University)

James Champion (University of Birmingham)

Neil Morrison (University of Leeds)

David Ferguson (Aberystwyth University)

Membership Subscription Reminder for 2014

Please note that the annual membership subscription fee for the British Society of Rheology for 2014 is due on 1st October 2013. If you haven't done so already, please arrange payment as soon as possible. Payment may be made by cheque, paypal or standing order. Our preferred method of payment, however, is by standing order since this reduces the administrative overhead. A payment form can be found on the website (<http://www.bsr.org.uk/renewal.asp>).

You may view your past payment history by logging into the BSR website. If you have forgotten your username and password please let me know and I will forward these on to you. Please check that your contact details stored on the website are correct so that we can ensure that notifications about conferences and meetings, for example, reach you.

Tim Phillips
BSR Membership Secretary

RHEOLOGY ABSTRACTS RIP – the end of an era

After continuous publication over the last 57 years, the time has now come to cease production of this journal. The last issue will be Volume 56, issues 3 and 4, to be published in early December.

The Abstracts started in the 1950s, when some of our founder members made summaries of the more important papers of the day, and circulated them among the membership. In those days, it was not the normal practice to publish a paper with an abstract, so this was a good way to ensure news of good rheological practice and theory was promulgated. The BSR was asked by Pergamon Press to put this on a more formal basis, and they would publish and advertise it to interested parties, sending each member of the Society a copy. This was very successful, and by the middle of the 1960s, over 300 institutions and companies subscribed. Pergamon Press (then owned by Robert Maxwell) also gave a (very) small percentage of the profits to the BSR. When Pergamon went under in 1992, Elsevier took over the publication, and suddenly the share of the profits increased substantially. Members of the Society would submit summaries/abstracts of papers (usually hand or type written) to the Abstracts Editor (by now an officer on the Council) who would collate them, arrange them into categories, so that they could be numbered, and latterly also did the index. (In the early years, indexing was done by another member of the Society, not usually on Council). The Editor then arranged to have them typed up into a form for publication (Elsevier paid the typist, who was normally in direct contact with the Editor). On request, the Membership Secretary would send the publisher a list of members, who would receive their copy of the Abstracts 4 times a year. This arrangement lasted for over 30 years, but as electronic access to papers became more common, the number of subscribers reduced. Initially, Pergamon, and then Elsevier, restricted the number of pages (and hence abstracts) published each year (keeping costs down). They then started increasing yearly subscriptions to maintain income as numbers fell. Finally, in 1995, they published their final volume (No 38) and handed over all documents to the BSR Council, who had decided to continue on their own. With a subscriber base of over 100, and all income coming directly to the Society, this was quite a windfall. It was decided that, as there were substantially more papers covering relevant aspects of Rheology than the numbers previously published, we could increase the number of pages published by a factor of 3 or 4. By also decreasing the font size, some 5 times as many abstracts were being gathered and published. The printing of the Bulletin had already been taken over by the Print Unit of the University of Strathclyde, so it was logical for them to also print the Abstracts. This arrangement has continued to this day, with the BSR covering all costs.

After the first 5 or 6 years, the number of subscribers had started to take a nose-dive (as predicted by Elsevier), and costs started to catch up with income. As we

had already taken the step of publishing the Abstracts on-line (and had even digitised all Volumes from the very start), the decision was taken, at an Extraordinary General Meeting, to cease sending members the hard copy of the Abstracts, since most would have access to the on-line version through the BSR website. This meant that we could continue producing the Abstracts for the subscribers, and reduce costs at the same time (maintaining a healthy balance sheet). However, the subscriber base has continued to dwindle, and with the numbers approaching single figures, the economics no longer add up. Though other possibilities were considered, Council thought it best to survey the membership to see if there was still a need for the publication. After a few replies, it became clear that Rheology Abstracts had run its course, and it was time to put it to rest.

It only remains for me to thank all those responsible for its production and distribution over the years; the many abstractors, previous Editors, typists, packers, the Print Units at Elsevier and Strathclyde, and anyone I may have missed.

Nick Hudson

Abstracts Editor 1997-2001, 2005-2010, 2012-2014

October 2013

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A note of thanks

Council would like to express their gratitude to Nick Hudson for his exceptional work with Rheology Abstracts. RA was conceived in 1957, when the list of abstracts was separated from the BSR Bulletin, and was for many years an extremely popular source of information on rheological publications, and an important generator of funds for the Society. Nick has been Abstracts Editor and/or BSR Publications Manager since 1996, as well as one of the abstractors, and has capably steered RA through major changes in publishing. The BSR thanks him fulsomely for this contribution.

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BSR Midwinter meeting 2013 “Coating, Printing and Painting”

16th-17th December 2013
Institute for Manufacturing
University of Cambridge

This meeting aims to provide an overview of current research in rheology particularly in its application to printing, painting and coatings, such as inkjet printing and spray painting. The meeting will run from mid-morning 16th December to after lunch on 17th December at the Institute for Manufacturing in Cambridge, with a dinner at Robinson College on the Monday evening.

Keynote Speakers

- Prof Detlef Lohse, University of Twente
- Dr Philip Threlfall Holmes, AkzoNobel
- Prof Rhodri Williams, Swansea University

Organising committee

Ian Hutchings (University of Cambridge)
Oliver Harlen (University of Leeds; o.g.harlen@leeds.ac.uk)

Registration is open via the website <http://conferences.bsr.org.uk/>

Student £80
BSR member £100
Non-member £120

The registration fee includes dinner on Monday night, lunches on Monday and Tuesday, and coffee breaks.

Contributed talks and Posters

Contributions for short oral or poster presentations are invited. Please submit a short abstract (max 250 words) by email to Oliver Harlen ([o.g.harlen @leeds.ac.uk](mailto:o.g.harlen@leeds.ac.uk)). The abstract deadline is 15th November for oral presentations and 6th December for poster presentations.

Accommodation

Robinson College are offering B&B accommodation at a cost of £69+VAT. You should book directly with the college using this link and the promotional code 21558. They can also provide parking.

Directions

The Institute for Manufacturing is on the Science site in West Cambridge, in the Alan Reece Building (17 Charles Babbage Road, Cambridge CB3 0FS)

Contact

Please direct enquiries to

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New Ordinary Council Member Biography

Dr Manlio Tassieri



Manlio Tassieri is a Research Fellow of The Royal Academy of Engineering/EPSRC and proleptic Lecturer within the Biomedical Engineering Division at The University of Glasgow.

He graduated as a Chemical Engineer from the Department of Chemical Engineering, The University of Naples “Federico II” in 2000. During his final year project, he developed two novel rheo-optical methods for determining interfacial tension in disperse polymer blends. After graduating, he continued collaborating with researchers in

Naples on a pioneering study of the shear induced clustering of gelling droplets in aqueous biphasic mixtures. This topic is of particular interest, for instance, to the food processing industry. Later, in 2000, he moved to a consultant designer post at TECNOSISTEMS.p.A. Whilst there, his main undertaking was to design ventilation and fireproof systems for underground railways. This involved contributions to the design of the Turin underground railway project associated with the 2006 Winter Olympic Games.

In 2003 he decided to follow his aspiration to become an academic researcher. To do this, he embarked on research in the field of Microrheology of semi-flexible bio-polymers at the School of Physics & Astronomy of The University of Leeds, from where he graduated with a PhD in 2007.

Following his PhD, he held a postdoctoral research position in the Polymer Science and Technology IRC at The University of Leeds, collaborating in the Microscale Polymer Processing project.

In 2008 he moved to the Division of Biomedical Engineering at The University of Glasgow to take up a Research Assistant post studying the use of optical tweezers to measure properties of biological cells.

In 2010 he was awarded a Royal Academy of Engineering Research Fellowship to combine Microrheological techniques with Microfluidic devices. The aim of this Fellowship is to deliver new sensitive tools that measure conformational changes

of biological systems at nano- and micro-length scales, occurring as a consequence of pathological phenomena and/or variations in the surrounding solutions (e.g. due to drug stimulation or osmotic changes).

In April 2013, he has been elected council member of The British Society of Rheology.

New President Biography

Prof. Rhodri Williams



Rhodri Williams entered the field of Rheology in 1982 when he took up his PhD studies at the Physics Department, UW Aberystwyth, under Mervyn Jones (BSR past President) and David Trevena. His PhD studies of cavitation phenomena led to a period as research assistant to Ken Walters FRS (BSR past President) involving experimental aspects of the extensional flow of mobile elastic liquids. In 1990 he was awarded an EPSRC Advanced Fellowship which he took up at the Department of Chemical Engineering, Swansea, to work on rheometric applications of shearwave propagation, work for which he received the BSR Annual Award (1997). He became a Reader in 1999 and was promoted to a

Chair at Swansea in 2001, establishing the Centre for Complex Fluids Processing and working closely alongside colleagues in the UW Institute of Non-Newtonian Fluid Mechanics. In 2004 he led an EPSRC Portfolio Partnership under which he established the EPSRC-NHS Clinical Haemorheology Laboratory at Swansea's Morriston NHS Hospital. His subsequent work on the development of haemorheological techniques for the detection and analysis of abnormal blood clotting led to a Royal Society Brian Mercer Award (2007) and a Royal Academy of Engineering Enterprise Fellowship (2012). A former BSR Treasurer, he is a Fellow of the Institute of Physics, the Institution of Chemical Engineers, the Royal Society for the Arts, the Learned Society of Wales, and is a recipient of a Royal Humane Society Honorary Testimonial.

The Society of Rheology 85th Annual Meeting Hilton Montreal Bonaventure, Montreal Quebec, Canada 14th -17th October 2013

Presentations at Society of Rheology meetings tend to maintain a very high level of quality and the 85th meeting, held in Montreal in Canada, was no exception. Plenary lectures were provided by Profs Theo van de Ven (McGill University), Pierre Carreau (École Polytechnique, Montreal), Gareth McKinley (MIT) and Patrick Underhill (Rensselaer Polytechnic Institute). Gareth McKinley gave the Bingham lecture in recognition of the award of his Bingham medal and Patrick Underhill gave the Metzner Award Presentation.

Prof. van den Ven's plenary lecture was concerned with the "Rheology of cellulose hydrogels". According to the speaker cellulose is the most abundant renewable biomaterial on earth and he estimated that there was 10^{14} - 10^{15} kg available! He noted that this fact was often cited in papers concerned with cellulose rheology but that a recent paper he'd reviewed had probably overreached their knowledge when they claimed that "cellulose was the most abundant biomaterial in the universe". Cellulose is a rigid linear molecular with molecular weight on the order of 1000 and is usually modelled as hollow cylinders of radius 10-20 microns and length 0.2 -5 mm. Uses for cellulose fibres include paper, heating, shelter, clothing ("viscose") and other textiles.

Prof. McKinley's Bingham Lecture was on "Critical Gels, Scott Blair and the Fractional Calculus of Squishy Materials". Gareth started his talk by paying tribute to Sean Collier, an MIT police officer recently killed in the line of duty. He then outlined the contents of his talk before concluding this opening with a quote from Don Plazek's Bingham Lecture (J.Rheol.40(6),1996) (mis)quoting Novalis (1772---1801): "To become properly acquainted with a truth, we must first have disbelieved it and disputed against it". Starting with the work of Scott Blair and his work on "quasi properties" (a class of quantities that differ from each other in dimensions of [M], [L] and [T] where [M] = mass, [L] = length and [T] = time: the units of quasi properties are Pa.s^n so the consistency index from the power-law model would be one example familiar to most rheologists), Gareth went on to explain how fractional calculus could be used to capture (linear) rheological behaviour for a range of "real world" materials through the use of so-called "spring pots". The familiar Maxwell and Kelvin-Voigt models are special cases embedded within this framework. For those interested the slides from the talk are available on Gareth's website.

In addition to the plenary lectures, there was an excellent variety of talks in 5 different parallel sessions. In the "polymer solutions" track, Michael Renardy (Virginia Tech.) gave a very interesting talk regarding the eigenfunctions of Hookean and FENE dumbbells and a key message appeared to be that the finite

extensionability parameter (L^2) did not have to be particularly large (~ 100) for the FENE model to approach the Hookean result ($L^2 \rightarrow \infty$). Edson Soares (Universidade Federal do Espírito Santo) talked about the effect of polymer degradation on turbulent drag reduction. They used a double concentric cylinder device on a controlled stress rheometer to measure the friction factor (torque) for various Reynolds numbers (rotation speed) for various aqueous polymer solutions. David James (University of Toronto) gave an excellent talk regarding the role of the first normal-stress difference in shear in flows with an extensional component. David convincingly showed that for a range of flows which are usually described as extension-dominated the normal-stresses generated by the shear component within them could actually be much higher than the extensional stresses generated as, although the strain rates were quite high, the total Hencky strain which could be generated in the extensional component generally struggled to exceed two.

Tracking track to the “Interfacial Phenomena” session, Adam Burbidge (Nestle) gave a fantastic talk exploring the kinematics of extensional coalescence of drop pairs and chains. In the experimental methods session an excellent paper was given by Michael Johnson, a student of Randy Ewoldt (University of Illinois at Urbana-Champaign), regarding the effects of surface tension on low-torque measurements in rotational rheometers. They showed that surface tension can produce a torque more than two orders of magnitude larger than the torque due to material deformation for liquids with viscosities close to that of water. This torque is caused by rotational asymmetry of the contact line with non-constant interface angle or non-constant surface tension around the contact line. The results have recently been published in *Journal of Rheology* (57(6), 1515-1532 (2013)).

The “non-Newtonian flows” session also had a number of interesting contributions. Christian Clasen (KU Leuven) discussed the different scaling behaviour observed in the thinning of weakly elastic jets: for capillary breakup experiments the self-similar dynamics is governed by an exponential thinning based on $t/3\lambda$ whereas for jets it appears that the scaling is $t/2\lambda$ and self-similarity is lost. Experimental measurements from Christian’s group were supported by numerical simulations by Oliver Harlen and Clare McIlroy (Leeds). Bhamin Khomami (University of Tennessee Knoxville) discussed recent simulations his group had conducted investigating the effects of polymers on the breakdown of large-scale Taylor vortex structures in turbulent Taylor Couette flow. Bhamin used direct numerical simulation to show that the polymers led to a drag *increase* and to use the simulation data to provide mechanistic insight in to how the polymers modified the vortices.

Rob Poole, Liverpool.

Commentary on the 339th Council Meeting of the BSR

Institute for Life Sciences, Swansea University

I must take this opportunity to thank the Immediate Past President Bill Frith and the BSR council for offering me the chance of joining the council as an ordinary member. Of course, the offer was proudly received and readily accepted.

As a new member of the BSR council it has (accidentally) fallen to me to provide the commentary on the 339th council meeting. This was my first meeting and it was held on the 10th of September 2013 at the Institute for Life Sciences, Swansea University.

On the day of the meeting, my induction started very early in the morning (~8am), i.e. when I met Nick Hudson at the car hire station of Cardiff Airport. The first lesson I learned was to not fully trust technology, i.e. the satellite navigator, but rather follow the advice of a wise rheologist with a printed map in his hands; which of course I didn't. As a consequence, at beginning of our journey we faced a twelve miles long two-way single line country road! Thankfully, once on the motorway, the journey proceeded smoothly while Nick was indoctrinating me on the BSR and anticipating what (almost certainly) would have been my first duty. Once arrived in Swansea at the Institute for Life Sciences, we had the pleasure of meeting Karl Hawkins who kindly offered us not only a revitalizing coffee at the local cafeteria but also a tour of The Clinical Haemostasis and Biomarker Research Unit, which is equipped with an impressive series of rheometers. The tour ended in the room where the BSR council meeting would have taken place just after lunch.

The council meeting opened with the newly elected president, Rhodri Williams, donning the chain of office and expressing his pride at joining a list of such illustrious presidential predecessors. Following were the apologies for absence, approval of the minutes of the previous meeting, and an efficient run-through of the list of matters arising from that meeting.

The Secretary read out the Treasurer's report in his absence. In the report it is stated that the Treasurer's forecast is a roughly break even by the end of the year. So, nothing to worry about. The Membership Secretary reminded all that subscriptions for 2014 are due on 1st October; but he is currently chasing 2013 non-payers. In addition, there have been five applications for membership in the last few days, which council accepted. The Membership Secretary also informed that currently the BSR counts 350 members.

The Bulletin editor noted that the most recent Bulletin (Vol. 54 issue #2) has been sent to the printers and should be with members very shortly (if not already). However, it is already available online and a news item has been added to the website to highlight its availability. The main theme of this edition of the Bulletin concerned the INNFM meeting on “Advances in Non-Newtonian Fluid Mechanics” held at Chicheley Hall in March 2013. The meeting contained a Mini-Symposium on “Theoretical Rheology” to commemorate the work of Prof. Russell Davies, who will be retiring from his current position as Head of the School of Mathematics at Cardiff University in December 2013. Moreover, a “From the Archives” section has been introduced. In this first installment an article on “Rheology in the Printing Ink Industry” from the very first Bulletin (of the then “British Rheologists Club”) has been included to coincide with the theme of the forthcoming midwinter meeting (on “coating, painting and printing”). The next issue of the Bulletin will contain an article from the Annual Award winner, Prof. Tim Phillips, together with another “from the archives” article and profiles of new council members.

Following the survey of members, it was agreed to wind-up Abstracts gracefully following the next issue, and to inform libraries of this. Council agreed to Nick’s proposal to offer perpetual electronic access to subscribers.

The president thanked Nick for his work with Abstracts.

The meeting was guided towards the conclusion by passing through minor points of discussion and it concluded with a reminder to the next Council meeting, which will be held in Cambridge on Tuesday the 17th of December 2013.

Manlio Tassieri
Ordinary member of Council

INDUSTRY NEWS

TA Instruments Acquires Scarabaeus Mess- und Produktionstechnik GmbH

New Castle, Delaware, USA. September 30, 2013 – TA Instruments today announced the acquisition of Scarabaeus Mess- und Produktionstechnik GmbH (Wetzlar, Germany), a privately held manufacturer of instrumentation and software for physical property measurements of rubber and rubber processing.

Terry Kelly, President of TA Instruments commented on the acquisition: “This market is a natural fit for TA Instruments. We have existing expertise and a large customer base using thermal analysis and rheology among rubber producers and manufacturers. Combining Scarabaeus products with our global support network will be a substantial benefit to scientists who produce and characterize rubber, polymers, and rubber compounds.”

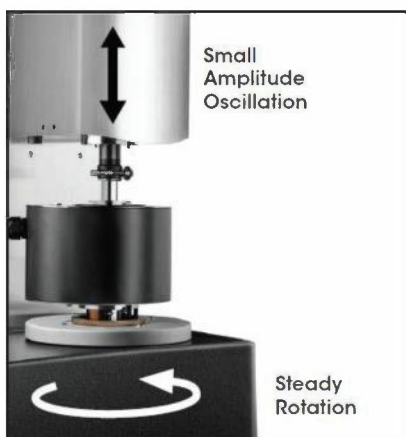
Key products developed by Scarabaeus include a Mooney Viscometer, Moving Die Rheometer (MDR), Rubber Process Analyzer (RPA), and automated density and hardness testers. Extensive automation and software that excels at tracking product performance over time makes these instruments particularly appropriate for manufacturing and process environments. The fully-featured RPA also includes many test features and analysis functions that are being used in the latest research and development efforts for rubber and materials technology, making it an equally appropriate match for upstream research laboratories.

Thomas Rauschmann, the founder of Scarabaeus and an innovator in rubber technology further commented, “The rubber industry is global, with manufacturing happening around the world for all major companies. TA Instruments’ worldwide service and support network will enable rubber producers and manufacturers to standardize on our rubber rheometers for uninterrupted productivity.”

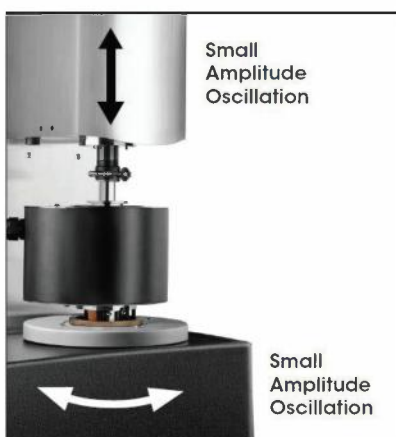
Orthogonal Superposition (OSP) and 2D SAOS

A new testing mode has been added to the ARES-G2: Orthogonal superposition (OSP). In orthogonal superposition, a sinusoidal oscillation strain is applied in the orthogonal (or perpendicular) direction to the standard rotational shear deformation of the rheometer. The geometry used to shear the sample is a modified double gap concentric cylinder. This is the only geometry that can perform such testing because the sample is sheared in two directions: rotationally with the motor and axially with the normal force transducer. The OSP deformation is obtained by driving the transducer in an oscillatory deformation mode in axial direction.

2D-SAOS is a combination of small oscillatory rotational and axial strain. In this mode a small oscillatory strain at the same frequency is applied in both, rotation and axial direction. The applied strain in rotational and axial direction has to be synchronized. The phase offset between the two input strain signals can vary from 0 to 90°. Two settings can be used; phase 0° (in phase) and phase 90° (out of phase). The benefit of this mode is to characterize anisotropy (dependence of material properties on the direction in space) in a material. If a material is isotropic, the measured moduli are independent of the direction, this means that the stresses measured from both shear directions would be the same and plotting one versus the other would result in a circle. If the material is anisotropic the measured moduli can be used to quantify the anisotropy as a function of time, deformation and frequency. Here the resulting stresses in both directions will be different and plotting them against each other will be different from a circle depending on the degree of anisotropy.



OSP



2D-SAOS

DMA mode: The ability to control an axial oscillation deformation in the normal force FRT has given the ARES-G2 additional functionality to perform pure DMA testing on the ARES-G2. Existing geometries such as parallel plates can be used for compression, and the Linear Film Fiber geometry for tension. Two new geometries are introduced on the ARES-G2: 3 Point bend and Dual/Single Cantilever. This mode is a major addition to the ARES-G2 platform as it gives the ability to have 2 instruments in one: a rotational rheometer along with a dynamic mechanical analyzer, and viscous heating, adapters for determining the pressure coefficient of viscosity and more.

Press release from Anton Paar

CTD180 – New Peltier Oven for all MCR Rheometers

This convection temperature device utilizes peltier technology to enable temperature control from -20°C to 180°C. The unit can be used with cone and plate / parallel plate configurations as well as solid sample fixtures such as the SRF (for DMTA type measurements) and the UXF (extensional measurements). Ovens utilising forced gas cooling can often struggle to control temperatures around ambient, peltier technology enables faster and more accurate temperature control across the whole of the CTD180 range. This oven is compatible with all generations of the MCR rheometer including the new TwinDrive MCR702.

For further information or assistance please contact

steve.goodyer@anton-paar.com

CONFERENCE DIARY

2013	CONFERENCES & MEETINGS
18 -21 Nov Rueil Malmaison France	5th Workshop on Viscoplastic Fluids: From Theory to Application Conference Organization: Patricia Fulgoni patricia.fulgoni@ifpen.fr Scientific Correspondent: Anthony Wachs VPF2013@ifpen.fr
16 -17 Dec Cambridge	BSR MWM2013: Coating, Printing and Painting Organising Committee: Ian Hutchings (University of Cambridge), Oliver Harlen (University of Leeds; o.g.harlen@leeds.ac.uk) Meeting Contact: Alice Cozens ac867@cam.ac.uk

CONFERENCE DIARY

2014	CONFERENCES & MEETINGS
8 -11 Apr Karlsruhe Germany	9th Annual European Rheology Conference (AERC 2014) Organiser/Contact details: German Rheological Society (DRG) Conference Contact: Prof. Dr. N. Willenbacher: Norbert.Willenbacher@kit.edu Prof. Dr. M. Wilhelm: Manfred.Wilhelm@kit.edu Conference website: http://www.aerc2014.kit.edu/
11-14 Apr Lake Vyrnwy Hotel, Wales	INSTITUTE OF NON-NEWTONIAN FLUID MECHANICS “Advances in Rheometry”. Conference Contact: Rhodri Williams (P.R.Williams@swansea.ac.uk) or Peter Townsend (p.townsend@swansea.ac.uk)
7 – 11 July Granada, Spain	14th International Conference on Electrorheological Fluids and Magnetorheological Suspensions Organiser/Contact details: University of Granada Conference Contact: Chair Modesto Torcuato López-López– Scientific Secretary ermr2014@gmail.com Conference Website: http://www.ermr2014.com/program
20 -25 July Melbourne, Australia	6th Pacific Rim Conference on Rheology Conference Contact: See website for details Conference Website: http://www.cvent.com/d/ycqx6z

2013	COURSES & WORKSHOPS
27-28th Nov 2013 St. Albans UK	Rheology Workshop Steve Goodyer, Anton Paar Ltd, Unit F, The Courtyard, St. Albans, Hertfordshire, AL4 0LA T: +44 (0)1992 514730; F: +44 (0)1992 514739 E: steve.goodyer@anton-paar.com

2014	COURSES & WORKSHOPS
13 - 15 May Glasgow	Process Rheology CONTACT: Dr Nick Hudson, Dept Pure & Applied Chemistry, University of Strathclyde, 295 Cathedral Street, Glasgow, UK T: +44(0)141 5482162; F: +44(0)141 5484822 E: n.e.hudson@strath.ac.uk

Discover the New HYBRID RHEOMETER



TA has combined powerful technology from the ARES-G2 with the core of our best selling AR products. Add in patented and patent-pending new technologies, and we've created the world's most powerful rheometer platform.



The Discovery Hybrid Rheometers feature the latest technical breakthroughs from TA:

- Patent-pending Optical Encoder Dual Reader for high precision displacement resolution
- Patented new low-inertia motor with unprecedented direct stress, strain, and rate control
- Force rebalance transducer (FRT) technology for normal force measurements
- Patent-pending True Position Sensor (TPS) for real-time gap corrections
- Smart Swap™ Geometries & Temperature Systems
- Second generation magnetic bearing for ultra low torque performance

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