
THE BRITISH SOCIETY OF RHEOLOGY

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$$\sigma^{(sp)}(t) = \mathbb{V} \frac{d^\alpha \gamma(t)}{dt^\alpha}$$

$$\sigma(t) + \frac{\mathbb{V}}{\mathbb{G}} \frac{d^{\alpha-\beta} \sigma(t)}{dt^{\alpha-\beta}} = \mathbb{V} \frac{d^\alpha \gamma(t)}{dt^\alpha}$$

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EDITORIAL

Welcome to Volume 55 (issue #1) of the British Society of Rheology Bulletin. In this issue we have; a very insightful article by Adi Jaishankar [MIT] on fractional constitutive equations; an article by the Vernon Harrison Award winner for 2012/3 – Robyn Cooke (née Moorcroft) [Durham University] – on the phenomenon of shear banding; some more “from the archives”, including an account of the very beginnings of the BSR. Finally I have also included a short piece on the most cited articles from the *Journal of Non-Newtonian Fluid Mechanics*: similar treatments for other rheology journals will follow in later issues.

Rob Poole, Liverpool March 2014.

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 Adi Jaishankar on fractional constitutive equations: the top equation is the constitutive equation for a “spring pot” (eq. 6 in lead article) whilst the lower equation is the fractional Maxwell model (eq.7). For definitions of the various terms in the equations – and the meaning of “spring pot” – please consult the article.

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.

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Fractional Constitutive Equations and the Rheology of Multiscale Materials

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In the lab as well as in daily life, we frequently encounter complex fluids that exhibit broad *power law* rheological responses. For example, performing a stress relaxation experiment on such a material would yield a relaxation modulus with time dependence of the form $G(t) \sim t^{-\alpha}$, with $0 < \alpha < 1$, i.e., the relaxation modulus decreases according to a power law function of time. Equivalently, a small amplitude oscillatory shear (SAOS) experiment would yield $G'(\omega), G''(\omega) \sim \omega^\alpha$, i.e., the viscoelastic storage and loss moduli, respectively, increase as power law functions of frequency. There are multiple reasons why multiscale power law response is exhibited. For example, crosslinking polymer gels undergo a transition from liquid-like to solid-like properties at a critical point, and exhibit power law relaxation for experimentally accessible timescales at this critical point.¹ Another source of multiscale relaxation arises from polydispersity in the sample; each molecular weight has its own characteristic relaxation time associated with it, and given a polymer solution with a broad distribution of molecular weights, a unique relaxation time cannot be identified. As a first approximation, one may think about the origin of the power law response in terms of the existence of a large number of relaxation modes, one each for a particular molecular weight in the distribution. However, because of the polydispersity, these multiple modes are very closely spaced. This leads to a broad, multiscale power law response in which no unique characteristic time scale can be identified.

Power law response also arises from the multiscale nature of the microstructure of many complex fluids. To a good approximation, the microstructure of these materials is fractal. Examples of such materials include physically and chemically crosslinked gels, emulsions, colloidal suspensions, and viscoelastic interfaces, to name a few. Therefore, a wide variety of industrially relevant complex fluids such as foods, cosmetics and

pharmaceuticals exhibit power law rheological responses. However the rheological behavior of such multiscale materials is not well described by classical viscoelastic models. Given their ubiquity and widespread applications, it becomes necessary to have models that can quantitatively describe these materials and make predictions of their rheological behavior under complex flow conditions.

One widely used technique to model power law rheology is by approximating the relaxation modulus $G(t)$ using a sum of exponentials (also called a Prony series):

$$G(t) = \sum_{i=0}^{\infty} G_i e^{-t/\lambda_i} \quad (1)$$

Note that the Prony series captures the idea of approximating a *continuous* power law as being a sum of *discrete*, and closely spaced, Debye relaxation modes. This works in theory; however in practice fitting power law-like data to a Prony series often involves using a large number of fitting parameters. The number of modes i required to fit data is dependent on the range of experimental data to be fit — the larger the range of data, the greater the number of modes required. This does not seem to be physically motivated from the point of view of characterizing a material. Moreover, the process of reducing what is in reality a continuous spectrum into discrete modes is an approximation. To quote from the work of G. W. Scott Blair, one of the founding fathers of modern rheology, “Normally, one is faced with the choice of selecting a large number of true properties or a smaller number of quasi-properties, since it is nearly always possible to express rheological behavior in terms of true properties provided enough constants are fitted. It is hoped to show that the latter course is by no means always the best.”² We expand upon what we mean by quasi-properties later in this article.

As rheologists we are all familiar with the concepts of Hookean springs and Newtonian dashpots. The stress in these elements follows from the Boltzmann superposition integral with a suitable choice of relaxation modulus $G(t)$:

$$\sigma^{(s)}(t) = \int_{-\infty}^t G(t-t') \dot{\gamma}(t') dt' = \int_0^t G \dot{\gamma}(t') dt' = G \dot{\gamma}(t) \quad (2)$$

$$\sigma^{(d)}(t) = \int_{-\infty}^t G(t-t') \dot{\gamma}(t') dt' = \int_0^t \eta_0 \delta(t-t') \dot{\gamma}(t') dt = \eta_0 \dot{\gamma}(t) \quad (3)$$

where $\sigma^{(s)}(t)$ and $\sigma^{(d)}(t)$ are the stresses at time t in the spring and the dashpot respectively, $\gamma(t)$ is the strain in the element at time t , $\delta(t)$ is the Kronecker delta function, G is the spring constant, and η_0 is the viscosity. These ideas of springs and dashpots are empirical concepts. There are no real springs or dashpots in the material; we simply visualize a material's viscous contributions to the stress as arising from dashpots, and it's elastic contributions arising from springs. This has proved to be a very successful modeling approach for a large class of materials. The Prony series extends these ideas by considering multiple parallel Maxwell modes, each with its own spring constant G_i and viscosity η_i , i.e., its own relaxation time $\lambda_i = \eta_i / G_i$. However, as Scott-Blair notes this empiricism may not be the best modeling approach for all materials.

It has been experimentally observed that many materials exhibit power law kernels with the relaxation modulus $G(t) = ct^{-\alpha}$, where c is a constant, and $0 < \alpha < 1$ as before. Motivated by this experimental observation, we use the Boltzmann superposition integral to obtain a new rheological element with the constitutive equation

$$\sigma^{(sp)}(t) = \frac{1}{\Gamma(1-\alpha)} \int_0^t \mathbb{V}(t-t')^{-\alpha} \dot{\gamma}(t') dt' \quad ; 0 \leq \alpha < 1 \quad (4)$$

in which $\sigma^{(sp)}(t)$ is the stress in this mechanical element. We have rewritten the constant $c = \mathbb{V} / \Gamma(1-\alpha)$ for reasons that we explain below. Koeller³ has called this element the *springpot* because one notes that for

$\alpha = 0$ and $\alpha = 1$, we obtain the constitutive equations of a Hookean spring and a Newtonian dashpot respectively.*

Consequently, this element interpolates between a spring and a dashpot for $0 < \alpha < 1$. The integral in Equation (4) is in fact mathematically identical to an operation known as the fractional derivative which is defined as^{4,†}

$$\frac{d^\alpha f(t)}{dt^\alpha} = \frac{1}{\Gamma(1-\alpha)} \int_0^t (t-t')^{-\alpha} \dot{f}(t') dt'; \quad 0 \leq \alpha < 1 \quad (5)$$

in which $f(t)$ is some function that has an ordinary derivative to order $[\alpha] + 1$, with $[\alpha]$ representing the integer part of α , and the overdot represents the first derivative with respect to time. Consequently, equations (4) and (5) enable us to rewrite the constitutive equation of the springpot as

$$\sigma^{(sp)}(t) = \mathbb{V} \frac{d^\alpha \gamma(t)}{dt^\alpha} \quad (6)$$

The constant $\mathbb{V}$ is a quasi-property and has units of $[\text{Pa s}^\alpha]$. For $\alpha = 0$ and $\alpha = 1$, $\mathbb{V}$ reduces to a Hookean modulus (units: Pa) and a Newtonian viscosity (units: Pa s) respectively. This means that $\mathbb{V}$ is intermediate between these two idealized material properties for all other values of α ($0 < \alpha < 1$). It has been argued² that a quasi-property is a measure of material *firmness*, which depends not only on the material properties, but also on the process being carried out to measure the firmness. Much detail can be found on quasi-properties in the publication by Scott-Blair et al.² We see from Equation (6) that we require only two parameters to characterize a springpot: the quasi-property $\mathbb{V}$ and the power law exponent α .

* Note that for $\alpha = 1$, for reasons of mathematical consistency, the constitutive

equation is written as $\sigma^{(sp)}(t) = \frac{1}{\Gamma(2-\alpha)} \int_0^t \mathbb{V} (t-t')^{-\alpha+1} \dot{\gamma}(t') dt'$. This

reduces to $\sigma^{(sp)}(t) = \int_0^t \mathbb{V} \dot{\gamma}(t') dt'$ for $\alpha = 1$. This is the same as the

constitutive equation of a Newtonian dashpot.

† There are some subtleties involved in the definition of the fractional derivatives. Here we only give the Caputo definition. Please see our previous work for more details on definitions and mathematical preliminaries⁷

One physical visualization of a springpot would be to think about it as being identical to a Newtonian dashpot with one key difference: we replace the Newtonian fluid inside the dashpot by a power law fluid to obtain a springpot. Similar to the concepts of dashpots and springs, this empiricism is experimentally motivated. We have already noted above that a number of complex fluids do indeed show power law relaxation and springpot-like behavior in standard viscometric flows. However a firmer physical basis for the springpot comes from the ideas of anomalous sub-diffusion that has been observed in power law materials, in which the root-mean-square distance traveled by a diffusing particle $\langle \Delta x^2 \rangle$ scales with time as $\langle \Delta x^2 \rangle \sim t^\alpha$, $0 < \alpha < 1$. Because of the multiple length scales present in the microstructure of the material, a diffusing particle is liable to get trapped in certain locations until it hops out and finds a channel to diffuse freely, only to be trapped again at some future time. Hence, instead of a regular random walk, this diffusion process is better modeled as a Continuous Time Random Walk (CTRW), in which both the step length of the diffusing particle as well as the waiting time between steps is sampled out of a power law distribution⁵. It can be shown⁶ this model leads to sub-diffusion with $\langle \Delta x^2 \rangle \sim t^\alpha$. Using the generalized Stokes-Einstein equation, we can directly relate this power-law sub-diffusive process to power law relaxation in bulk rheology, and it is this power law kernel we use in our definition of the constitutive equation of the springpot (equation (4)).

We may now incorporate these springpot elements into standard mechanical models such as the Maxwell model or the Kelvin-Voigt model and generalize them to their fractional equivalents. For example, the fractional Maxwell model (FMM) is obtained by generalizing both the spring and the dashpot connected in series in the Maxwell model to two springpots connected in series. The constitutive equation of the FMM is given by⁷

$$\sigma(t) + \frac{\mathbb{V}}{\mathbb{G}} \frac{d^{\alpha-\beta} \sigma(t)}{dt^{\alpha-\beta}} = \mathbb{V} \frac{d^\alpha \gamma(t)}{dt^\alpha} \quad (7)$$

where α, β and $\mathbb{V}, \mathbb{G}$ are the power law exponents and quasi-properties of the two springpots respectively. By convention, we take $\alpha > \beta$. We note that setting $\alpha = 1$ and $\beta = 0$ in the above equation, we retrieve the constitutive equation of the standard Maxwell model. Note that a single

springpot has no characteristic time scale; however when two springpots are present in the model, the relaxation modulus exhibits a transition from one power law to the other (each power law regime being dictated by one of the springpots) and this transition occurs at a characteristic time scale given by $\tau = (\mathbb{V} / \mathbb{G})^{1/(\alpha-\beta)}$. Equation (7) is a linear ODE, and therefore the techniques of Laplace and Fourier transforms may be applied to the constitutive equation above and we easily obtain viscometric functions such as the storage and loss moduli $G'(\omega)$ and $G''(\omega)$ respectively, the relaxation modulus $G(t)$ or the creep compliance $J(t)$. In a similar manner, the constitutive equation and the linear viscometric functions for the fractional Kelvin Voigt model (two springpots in parallel) may be obtained.

In Figure 1a we show an example of the FMM fit (lines) to SAOS frequency sweep data (symbols) obtained for a plant polysaccharide extract known as Mamaku gum.⁸ The values of the power law exponents and quasi-properties are given in the caption. It can be seen that using just four parameters we obtain a good fit over four decades of frequency range. Similarly figure 1b shows a fit of the FKVM containing a spring and a springpot in parallel (3 parameters) to a frequency sweep performed on a fluoro-silicone polymeric gel (Data obtained from Wyatt et al.⁹). In this case too, we see that the linear viscoelastic behavior of the material over many decades of frequency is accurately captured, including the power law regime observed at high frequencies. We note that the number of parameters used to obtain these fits (3 or 4) is markedly less than what would be required if a Prony series was used to describe the same data to the same degree of accuracy. Although we do not show it here for reasons of brevity, it can be verified that these two models can capture the linear viscoelastic behavior of a wide range of power law materials with at most four parameters. For more complicated rheological responses, additional springpots can be added in series or parallel until the desired physics of the material response is captured.¹⁰

Once a power law material has been characterized, i.e., the power law exponents and the corresponding quasi-properties in the fractional constitutive equation have been determined (cf. Equation (7)), we may use them to make predictions of the material response in other linear experiments, as demonstrated in our previous work.⁷ Furthermore in a

publication currently under review, we demonstrate how in addition to linear viscoelasticity, predictions of the nonlinear rheology of power law materials can also be obtained from an appropriate choice of fractional constitutive equation.¹¹ We provide an example of such a prediction in Figure 2, where we present the predictions obtained for the steady shear viscosity $\eta(\dot{\gamma})$ versus shear rate $\dot{\gamma}$. To generate this prediction, we use a fractional generalization of the standard linear solid with only four linear viscoelastic parameters, namely, a zero shear viscosity η_0 , infinite shear viscosity η_∞ , a springpot with quasi-property $\mathbb{G}$ and power law exponent β , and one additional nonlinear parameter. A characteristic time scale τ naturally arises out of this model, and is given by $\tau = ((\eta_0 - \eta_\infty) / \mathbb{G})^{1/(1-\beta)}$. Note that all the parameters in this model can be experimentally determined. Figures 2a and 2b show, respectively, the effect of varying τ and β on the steady shear viscosity $\eta(\dot{\gamma})$ as a function of shear rate $\dot{\gamma}$, all other parameters being held constant. It is observed that changing τ shifts the onset of the shear thinning regime, while a variation in β controls the power law slope of this regime. In fact, we note that the response this model gives us is identical to the Carreau model.¹² However, the benefit of using a fractional model to arrive at this result is that in addition to generating the nonlinear flow curves, we also obtain expressions for linear viscoelastic response (for example $G'(\omega)$ and $G''(\omega)$). More details on the model, including determining the nonlinear Carreau-like behavior, the comparison of its predictions with data and expressions for the linear viscoelastic response of this model may be found in our forthcoming publication.¹¹

In summary, fractional constitutive equations provide an ideal framework to model the rheology of complex fluids exhibiting power law behavior. The springpot may be thought of as being the building block of fractional constitutive equations. The existence of such elements is motivated not only by a wealth of experimental data, but also by physically based arguments in terms of anomalous sub-diffusion observed to occur in such fractal-like multiscale systems. With just a few model parameters, both linear and nonlinear rheological predictions of rheological response can be obtained, without the need for any fitting parameters. The quasi-properties

and power law exponents can be determined from just one linear experiment (say SAOS) and the nonlinear parameter can be determined from one set of step strain experiments at large (nonlinear) strains. An interesting area for future exploration is to understand the exact relationship between the fractional exponents α , β , the quasi-properties $\mathbb{V}$, $\mathbb{G}$ and the fractal properties of the microstructure of the material.

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Figures

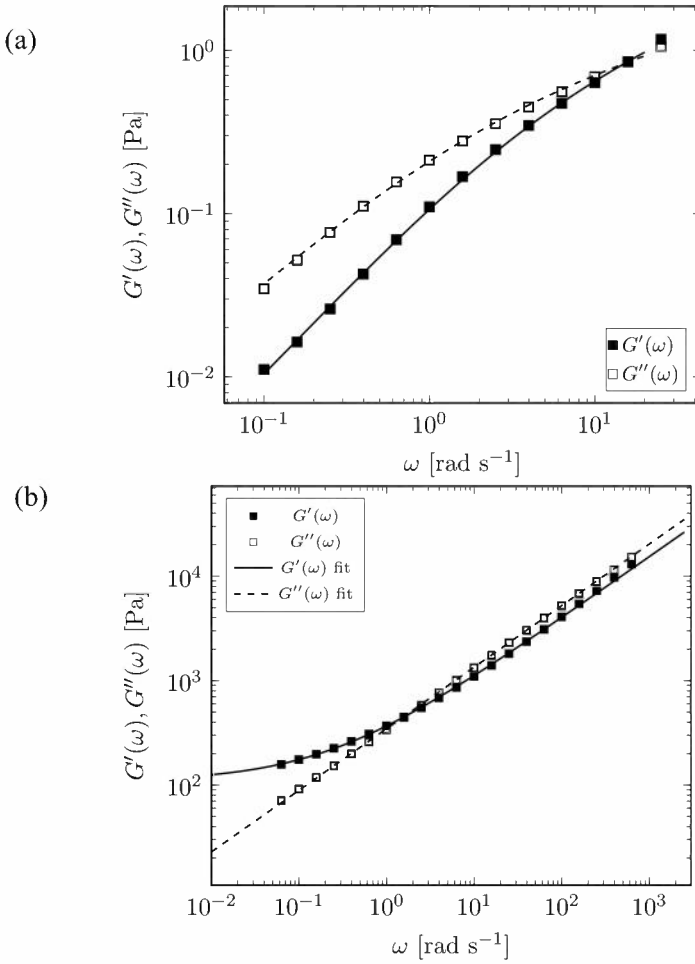


Figure 1: Examples of fractional constitutive equations fit to SAOS data
(a) Fractional Maxwell model (FMM) fit to Mamaku gum. FMM parameters are $\alpha = 1$, $\beta = 0.45$, $\mathbb{V} = 0.49$ Pa s, $\mathbb{G} = 0.39$ Pa s $^\beta$. (b) Fractional Kelvin Voigt Model (FKVM) fit to Flurosilicone polymer. FKVM parameters are $\alpha = 0.59$, $\mathbb{V} = 433.5$ Pa s $^\alpha$, $G = 108.3$ Pa.

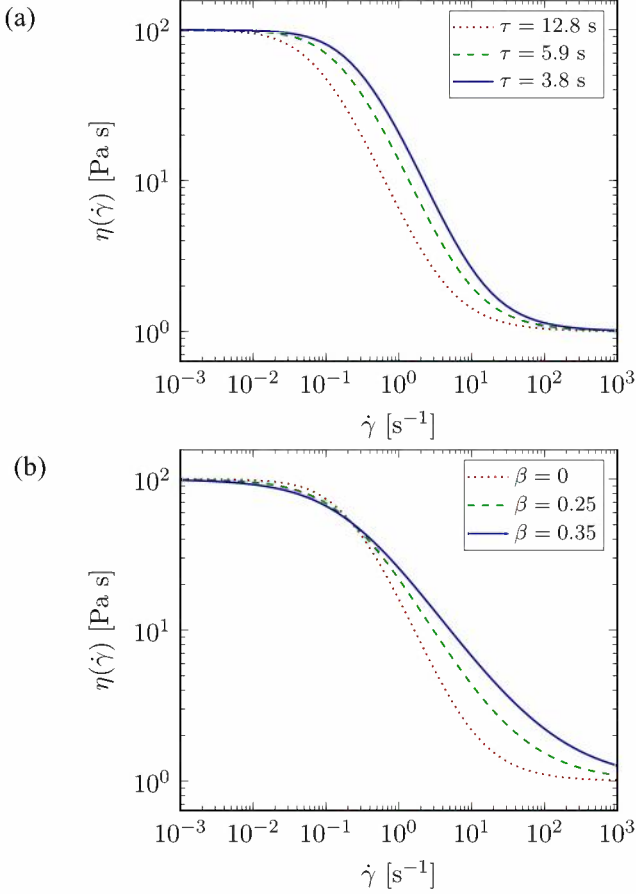


Figure 2: Carreau model behavior obtained using a fractional constitutive equation. $\eta_0 = 100$ Pa s and $\eta_\infty = 1$ Pa s. Subfigures (a) and (b) show the effect of varying $\tau = ((\eta_0 - \eta_\infty) / \mathbb{G})^{1/(1-\beta)}$ and β respectively, while holding all other parameters constant.

Shear banding in time-dependent flows of complex fluids.

Robyn Cooke (née Moorcroft)

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The subject of my PhD thesis concerned a shear-induced phenomenon commonly seen in complex fluids called ‘shear banding’, whereby an initially homogeneous material separates into macroscopic ‘shear bands’ of differing viscosity that coexist at a common shear stress under an applied shear flow [1, 2].

Shear banding has been observed in a vast range of materials such as entangled polymeric fluids, colloidal glasses, emulsions and foams. Most studies on such materials investigated the steady state behaviour, for which the criterion for the existence of shear banding is a negative slope in the underlying constitutive curve [3]. More recently though, there has been much research on the time-dependent rheological response of complex fluids during the initial startup of deformation, before a steadily flowing state is established. It has been shown that time-dependent shear banding can arise during this response in materials with different underlying structure, indicative of a generic underlying cause for the onset of time-dependent shear banding.

In my PhD thesis I investigated three fluid-universal, deformation-specific criteria [4] for the onset of shear banding during the time-dependent response of complex fluids to three deformation protocols: step stress, shear startup and strain ramp. I applied these generic criteria to specific models for entangled polymeric materials (using the rolie-poly (RP) model [5], Giesekus model [6], and a recent glassy polymer model [7]) and soft glassy materials (using the Soft Glassy Rheology (SGR) model [8] and a simple fluidity model [9]). The results of my thesis pertain to the formation of shear bands during the time-dependent response to shear flow before a steadily flowing state is established. They therefore not only describe how steady state shear bands are established from such a flow in systems that show steady state banding, but also describe the formation of transient shear bands, and the subsequent return to homogeneous shear, in systems that do not necessarily band at steady state.

In step stress, I showed that the RP and Giesekus models show qualitatively similar time-dependent responses of the shear rate [10]. In these models, for imposed stresses nearest those on the weakest slope of the constitutive curve, the shear rate shows an initial decrease (“creep”) followed by a sudden, dramatic increase over several orders of magnitude in a short time (“fluidisation”), in qualitative agreement with experimental results of entangled polymeric materials. In this protocol the criterion for the onset of linear instability to shear banding is the simultaneous occurrence of positive curvature and slope of the shear rate as a function of time. That is, the onset of time-dependent shear banding is concurrent with the onset of fluidisation [4]. I confirmed that such shear bands arise in these models, but showed that they only become significant in the RP model: bands in the Giesekus model remain negligibly small.

Recent experimental and theoretical work in soft glassy materials has shown that shear banding can arise at the onset of fluidisation (the “fluidisation time”) [11]. Motivated by these results, I determined a relation for the fluidisation time in the SGR model as a function of the model’s parameters and the material’s age.

Finally, I showed that a recent glassy polymer model [7] has similar behaviour in step shear stress as it does in extensional loading whereby fluidisation is curtailed by the onset of strain hardening. This strain hardening also acts to reduce the magnitude of transient shear banding that arises with fluidisation [12].

In shear startup, ‘elastic’ and ‘viscous’ contributions to linear instability to shear banding were identified and related to negative slopes of: the shear stress in strain in the time-dependent response (“elastic”), and of the shear stress as a function of shear rate at steady state (“viscous”) [4,10]. Using these I showed that, regardless of the shape of the constitutive curve, time-dependent shear banding arises in the RP model for imposed shear rates that are faster than the reptation rate but slower than the stretch relaxation rate. Shear banding then persists to steady state for shear rates that also lie on the negative slope of the constitutive curve. In contrast, I showed that no significant transient shear banding arises in the Giesekus model; shear banding only arises as the system nears steady state for shear rates in a negatively sloping region of the constitutive curve [10]. This is due to a

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Thermo Scientific HAAKE RheoScope module: image acquisition at (very) high shear rates using a stroboscope light source

Key words

Thermo Scientific HAAKE MARS, Thermo Scientific HAAKE RheoScope module, Stroboscope light source, Data acquisition at high shear rates, Emulsions, dispersions

The optionally available stroboscope light source extends the capabilities of the HAAKE RheoScope module, facilitating on the one hand an investigation of rheological phenomena on a structural level also at (very) high shear rates and providing on the other hand an improvement of the quality of the microscopic images at lower shear rates due to a shorter exposure time and a higher light intensity.

Thanks to the stroboscope light source, e.g. the behavior of paints and inks during the coating process can be investigated with the RheoScope or the coalescence of emulsion droplets under high shear rates. Shear-induced orientation and deformation in a sample as well as the structural disaggregation and recovery under defined temperature and shear conditions are further examples.

Instead of using a cold light source, a stroboscope (model BVS-II Wotan, Polytech GmbH) can be connected to the RheoScope module using the same light guard. This modification can be made done by the user within seconds without any tools. The stroboscope light source is equipped with a Xenon flash lamp and has a maximum flash frequency of 200 Hz. In order to synchronize the microscopic data acquisition with the flash light of the stroboscope, only the integration time of the camera in the HAAKE RheoWin software needs to be adapted.

High quality images can be obtained up to a shear rate of $44\,000\text{ s}^{-1}$ using the HAAKE RheoScope camera in combination with the stroboscope light source. Based on experience and depending on the individual sample, images up to a shear rate of 2000 s^{-1} can be taken with a cold light source. This means, that the use of a stroboscope light source with the HAAKE RheoScope module extends the measuring range by factor of 20.



Thermo Scientific RheoScope module

In Fig. 1 microscopic images of a dispersion of mineral oil in silicone oil are depicted at three different shear rates using a cold light source (Fig. 1a - c) and a stroboscope (Fig. 1e - f). A plate/plate measuring geometry with a diameter of 35 mm and a polished surface using a measuring gap of $50\text{ }\mu\text{m}$ was used. Significant differences are already visible at a shear rate of 1290 s^{-1} (Fig. 1b and 1e): Images taken using a stroboscope have a much higher quality than those obtained with a cold light source. Fig. 2 shows, that high quality images up to a shear rate of 44000 s^{-1} can be taken using a stroboscope light source.

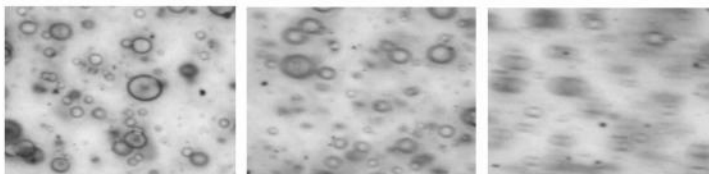


Fig. 1a - c: Images taken using a cold light source at different shear rates: 630 s⁻¹ (1a), 1290 s⁻¹ (1b) and 2520 s⁻¹ (1c)

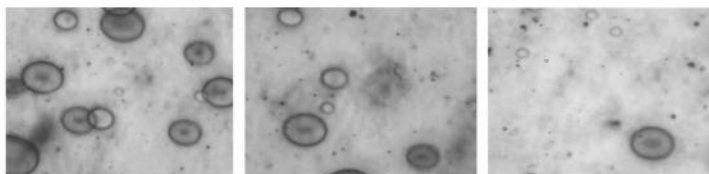


Fig. 1d - f: Images taken using a stroboscope light source at different shear rates: 630 s⁻¹ (1d), 1290 s⁻¹ (1e) and 2520 s⁻¹ (1f)

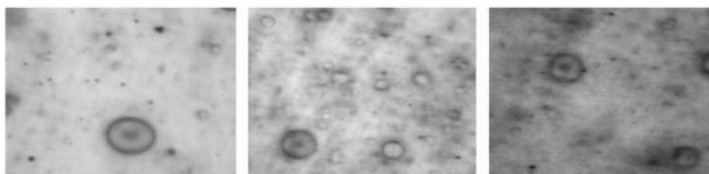


Fig. 2a - c: Images taken using a stroboscope light source at higher shear rates: 5670 s⁻¹ (2a), 12600 s⁻¹ (2b) and 44000 s⁻¹ (2c)

Order information

222-2050 Optional accessory for HAAKE RheoScope module: Stroboscope light source with Xenon flash lamp with maximum flash frequency of 200 Hz (85 V – 265 V / 50 Hz – 60 Hz)

thermoscientific.com/mc

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stabilising contribution to linear stability that is non-negligible in the Giesekus model; this contribution is however negligible in models that behave as nonlinear elastic solids during the time-dependent response (such as the RP model). With regard to soft glassy materials, I showed that age-dependent shear bands arise transiently in a scalar fluidity model that has a monotonic constitutive curve, consistent with the “elastic” contribution to instability described above [9]. Finally, it was again shown that strain hardening reduces the magnitude of transient shear banding in the GP model.

In the final chapter of my thesis I investigated stress relaxation in the RP model after strain ramps of rates that probe the chain stretch relaxation rate [10]. The general criterion here states that any fast ramp that ends as the stress is a decreasing function of strain will be unstable to the onset of banding immediately *after* the ramp has ended [4]. I used this to show that after ‘slow’ ramps in the RP model (relative to the stretch relaxation rate, but which are still much faster than reptation) linear instability to heterogeneity arises for strain amplitudes > 1.7 , and that ‘fast’ ramps (relative to the stretch relaxation rate) of the same amplitude result in a delayed onset of linear instability, provided convective constraint release is sufficiently inactive [10]. I also showed that the Lodge-Meissner relation holds during stress relaxation in the RP model (with shear homogeneity enforced) after ramps of *any rate or amplitude* and *any parameter values* in the model, with one exception: ramps performed at rates much slower than the stretch relaxation rate violate the LM relation *only* when convective constraint is active ($\beta \neq 0$). This result assumes shear homogeneity: with shear heterogeneity allowed I showed that the LM relation is violated after ramps for which shear banding becomes significant during stress relaxation.

In summary, my research investigated the link between rheological features commonly seen in a variety of complex fluids with the onset of shear banding during the time-dependent responses to step stress, shear startup and strain ramp protocols. In doing so, I have explored the time-dependent banding behaviour of several well known models for entangled polymeric and soft glassy materials.

I am sincerely grateful to Suzanne Fielding for her excellent supervision throughout my PhD. I also thank those I have had the pleasure of working

with: Peter Olmsted, Stephen Agimelen, Mike Cates, Ron Larson, Peter Sollich, and Richard Graham, and thanks also to the EPSRC for funding. Finally, I am honoured to have been awarded the Vernon Harrison Doctoral Prize, my thanks go to the BSR for awarding it to me.

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A citation metrics analysis of the Journal of Non-Newtonian Fluid Mechanics¹

The first issue of the *Journal of Non-Newtonian Fluid Mechanics* (“JNNFM”), founded by Ken Walters FRS (BSR President 1974 –76, BSR Gold medal winner 1984), was published in 1976. This first issue included papers written by Giovanni Astarita, Mort Denn, Ralph Oliver (BSR President 1992-94), Peter Townsend (BSR President 1996-98) and Ken Walters. Since that time more than 3000 articles have been published in 200 volumes. The current Editors are Mike Graham and Fernando Pinho.

In total all of the papers published in JNNFM have been cited 62125 times which corresponds to an average citation per article of 18.8. **Figure 1** below shows the number of papers published in each year for the past twenty years (left hand side plot) together with the number of citations in each of these years (right hand side plot).

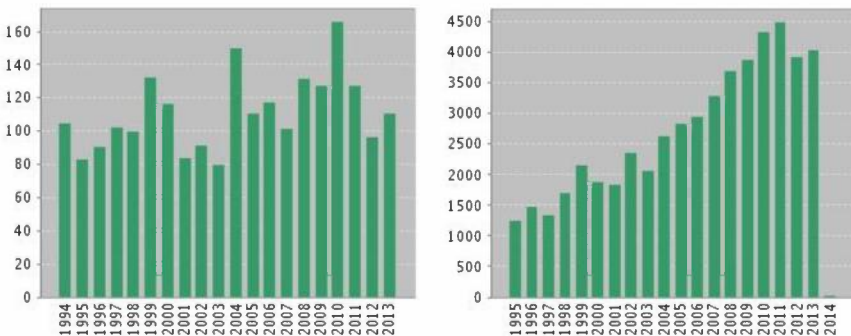


Figure 1: Number of papers published each year in JNNFM (left hand side), number of citations to JNNFM articles each year (right hand side)

¹Determined using *Web of Science* (all citation databases). Census date 12/01/2014

Of the 3,309 articles published by the beginning of 2014, only 56 of these articles have been cited more than 100 times (roughly 3% of the total). About 280 papers have never been cited although, if papers published in the last year are excluded from this analysis, this reduces to 196 (or about 6% of the total).

The 10 most highly cited papers in JNNFM contain, perhaps not unsurprisingly, a number of review articles. The first, third and fifth highest cited papers are all review articles written by Howard Barnes (BSR President 1995-96). Two of the top 10 articles are review articles on *thixotropy*: one of these is the aforementioned by Barnes (1997) and another by Jan Mewis (1979) (Jan Mewis was awarded the BSR Gold medal in 2005). The rest of the top 10 is comprised of papers devoted to either constitutive equations (#2 by Giesekus (BSR Gold medal 1990), #9 by Marrucci) or to numerical methods (#4 by Marchal and Crochet (BSR Gold medal 1994), #6 by Hieber and Shen and #10 by Guenette and Fortin). The eighth highest cited paper is David Boger's (BSR Annual award 1983, Gold medal 2004) famous work on "highly-elastic constant viscosity fluids" which are now universally known as *Boger* fluids as a consequence of this work. We note that the newest paper on the list is still 15 years old.

#1 A REVIEW OF THE SLIP (WALL DEPLETION) OF POLYMER-SOLUTIONS, EMULSIONS AND PARTICLE SUSPENSIONS IN VISCOMETERS - ITS CAUSE, CHARACTER, AND CURE

Author(s): BARNES, HA

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **56** Issue: **3** Pages: **221-251** DOI: **10.1016/0377-0257(94)01282-M** Published: **MAR 1995**

Cited 376 times

#2 A SIMPLE CONSTITUTIVE EQUATION FOR POLYMER FLUIDS BASED ON THE CONCEPT OF DEFORMATION-DEPENDENT TENSORIAL MOBILITY

Author(s): GIESEKUS, H

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **11** Issue: **1-2** Pages: **69-109** DOI: **10.1016/0377-0257(82)85016-7** Published: **1982**

Cited 374 times

#3 Thixotropy - A review

Author(s): Barnes, HA

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **70** Issue: **1-2** Pages: **1-33** DOI: **10.1016/S0377-0257(97)00004-9** Published: **MAY 1997**

Cited 368 times

#4 A NEW MIXED FINITE-ELEMENT FOR CALCULATING VISCOELASTIC FLOW

Author(s): MARCHAL, JM; CROCHET, MJ

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **26** Issue: **1** Pages: **77-114** DOI: **10.1016/0377-0257(87)85048-6** Published: **NOV 1987**

Cited 364 times

#5 The yield stress - a review or ' π alpha nu tau alpha rho epsilon iota' - everything flows?

Author(s): Barnes, HA

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **81** Issue: **1-2**

Pages: **133-178** DOI: **10.1016/S0377-0257(98)00094-9** Published: **FEB 1999**

Cited 359 times

#6 A FINITE-ELEMENT-FINITE-DIFFERENCE SIMULATION OF THE INJECTION-MOLDING FILLING PROCESS

Author(s): HIEBER, CA; SHEN, SF

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **7** Issue: **1** Pages: **1-32** DOI: **10.1016/0377-0257(80)85012-9** Published: **1980**

Cited 318 times

#7 Title: THIXOTROPY - GENERAL-REVIEW

Author(s): MEWIS, J

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **6** Issue: **1** Pages: **1-20** DOI: **10.1016/0377-0257(79)87001-9** Published: **1979**

Cited 250 times

#8 HIGHLY ELASTIC CONSTANT-VISCOSITY FLUID

Author(s): BOGER, DV

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **3** Issue: **1** Pages: **87-91** DOI: **10.1016/0377-0257(77)80014-1** Published: **1977**

Cited 236 times

#9 Dynamics of entanglements: A nonlinear model consistent with the Cox-Merz rule

Author(s): Marrucci, G

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **62** Issue: **2-3**

Pages: **279-289** DOI: **10.1016/0377-0257(95)01407-1** Published: **FEB 1996**

Cited 235 times

#10 A NEW MIXED FINITE-ELEMENT METHOD FOR COMPUTING VISCOELASTIC FLOWS

Author(s): GUENETTE, R; FORTIN, M

Source: JOURNAL OF NON-NEWTONIAN FLUID MECHANICS Volume: **60** Issue: **1** Pages: **27-52** DOI: **10.1016/0377-0257(95)01372-3** Published: **OCT 1995**

Cited 228 times

The person who has published the most papers in JNNFM is Roger Tanner (BSR Gold medal 2000): Roger's 62 articles have been cited 1861 times. His highest cited paper - O'Donovan and Tanner (1984) - is concerned with numerical modelling of a Bingham fluid (121 citations). Roger has contributed to 2% of all JNNFM papers and these papers have garnered 3% of the journal's total number of citations.

Rob Poole, Liverpool

"From the archives"

Circular No. 9 August 1945

A LETTER TO MEMBERS OF THE BRITISH RHEOLOGISTS' CLUB
From the Honorary Treasurer.

"INGLEMERE,"

DAGDEN ROAD, SHALFORD,
GUILDFORD, SURREY.

August 20, 1945.

DEAR FELLOW MEMBER,

At the next Annual General Meeting of this Club I shall have to ask for authority to increase your subscription from the present 5/- to £1-0-0. This is a step which your Committee much regrets, but I believe that when the circumstances are explained, you will see the reason for it.

When Dr. Scott Blair, Dr. Lang and I started this Club in October 1940, we thought we should probably have a membership of about 40; and we thought that a subscription of 5/- would cover the costs of postage and stationery and any other small expenses that might be involved. We never thought that the membership would swell to about 300—and it is still increasing. The size of our Club now makes it necessary that we should secure some part-time assistance for our Secretary.

During the past five years Dr. Scott Blair has carried out his duties as Hon. Secretary only with the help of Miss Milligan, who has done the work of duplicating and addressing envelopes; and I know that if the history of this Club ever comes to be written, it will record the heavy debt which the Club owes him. A new Hon. Secretary will be appointed at the Annual General Meeting, but your Committee has agreed that we cannot, as a Club, expect him to shoulder this quite heavy burden (which has to be done very largely in spare time) without remuneration or paid assistance.

Unfortunately, the mathematics of the position are very simple. We have no source of income apart from subscriptions. 30 subscriptions of 5/- give a total of £75, which is enough to cover present costs of postage and printing and incidental expenses—but that is all. To provide adequate paid secretarial assistance we shall have to raise about £150; and now that the war is over and we are intending to increase our activities, expenses are bound to increase as well. We are therefore aiming at an annual income of about £300.

This proposed increase in subscription will not take effect without the approval of the membership as expressed at the Annual General Meeting, and opportunity will be given for expression of views on the subject. The purpose of this letter is only to let you know beforehand what the position is. We regret that a higher rate of subscription has become necessary, but think that you will agree that it cannot well be avoided.

Yours truly,

V. G. W. HARRISON,
Hon. Treasurer.

[Editor's note: www.bankofengland.co.uk claims £1.00 in 1945 money is worth £36.54 in today's money...subscribers please take note of current value for money of fees]

Bulletin No. 11 June 1946

Visit to the National Physical Laboratory, Teddington, Saturday afternoon, 15th June, 1946.

An interesting Club meeting was held at the National Physical Laboratory, by the courtesy of the Director, when about a hundred members and guests attended. Dr. Guy Barr spoke on recent developments in viscometry, including the calibration and design of standard viscometers.

After giving a survey of early ideas on viscosity, Dr. Barr stressed the importance of kinematic viscosity in relation to hydraulics and aerodynamics. With regard to standard viscometers Dr. Barr described the Gruneisen, Fenske and Ubbelohde suspended level viscometers which were designed to minimise errors due to any lack of verticality in use of the U-type of viscometers. Small discrepancies in results recently obtained with carefully calibrated viscometers by observers at home and overseas (Joint meeting of Institute of Petroleum and British Rheologists' Club, J.Inst. Petrol, **31**, No. 260, August, 1945) have been traced to surface tension differences in the calibrating liquids used.

Dr. Barr described experiments and exhibited viscometers designed to eliminate the surface tension difficulty. A short interesting discussion followed and the members and guests visited laboratories where investigations of a rheological character were in progress: these included the silting of harbours, the slow creep of metals, the ventilation of buildings, plastics, use of strain gauges, etc. E.W.J.M.

Bulletin No. 13 December 1946

My dear Scott Blair,

Some time ago you asked me to jot down my recollections of how the Club came into being, and something of its first few years. Please take these jottings as my hurried attempt to meet your request—I never could resist them. One can never tell who in the future will peruse these scribbles and what they will read into them. If they do no more than help to keep something of that delightful informal spirit with which we started, I shall be more than pleased. Here, then, is my own story:—

It was a fine summer afternoon in 1940 and, feeling somewhat exhausted by the difficult war conditions of evacuation to Reading, I went a little way into the country with my wife. Begrudging the few hours away from the temporary office of the Institute of Physics, I consoled myself by fulfilling a long-standing promise to visit Scott Blair's laboratory at the National Institute for Research in Dairying, at Shinfield, some three miles out of Reading. He explained to me the difficulty he was having in devising suitable instruments for measuring the rheological properties of the secretions from the uterine cervix of the cow, which he thought might prove a useful early test for pregnancy—a matter of great importance to the dairy industry during the war. It immediately occurred to me, from what he said, that this problem was very similar to V. G. W. Harrison's, who was trying to measure the rheological properties of printing inks. In the normal course of my work as Secretary of the Institute of Physics, I therefore gladly arranged for these two to meet. That meeting must be taken as the first meeting of the Club, that it was of mutual benefit seems certain, for they came to me and asked if there were not a few more interested in these problems, and that I should bring them all together. There were the paint industry people, the oil and tar people, and so on, and we thought there might be twenty or more who would like to lunch together two or three times a year to 'swap

yarns,' and to arrange to visit each other's labs. We three appointed ourselves a Committee, having decided to form a Club, which should have no rules and no formalities like scientific and learned societies—indeed, a Club, where one could speak as freely as in the lab. The Committee was to meet either in my attic room in the University of Reading (the old red building) or in Scott Blair's drawing-room. The latter were the more successful meetings since we had the great advantage of Mrs. Scott Blair's wisdom and teas, not to mention Wolfgang, the dog, who was always present. Harrison came over from Guildford on his motorbike—dressed as for Arctic exploration, which was no doubt necessary. The Board of the Institute of Physics permitted the clerical work for the Club to be done in its temporary office for the first few years of its existence, so long as it did not interfere too much with official work. When it did, Mrs. Lang came to the rescue and cut the stencils for the Bulletins and Abstracts, which were then rolled in my office. The Committee meetings were great fun—as we all had a goodly dose of Committee work in our daily work we were glad to have these most informal meetings, breaking all the rules of procedure. Later when we found that the Club was shockingly successful, and we were in danger of founding yet another scientific Society, with its publications and office problems, we thought it wise to make the Committee more representative of the Club, so Treloar and Broome joined us. They thought it time we had a Chairman and I had the honour of being pushed into that office. This I was glad to accept, for I confess I used to try out techniques learnt from Chairmen I had seen at work during the last ten years. Perhaps some less biased pen than mine will record something of the Committee's thereafter.

As the Club grew in numbers and status, its office work grew. There was the idea, for example, of producing duplicated copies of translations of original classical rheological papers; in particular one by Pochettino which ran to many pages of typescript. This was done in odd times in my office and was very troublesome. Indeed, in 1942, the time had clearly come to take the Club's activities more seriously before they become a menace and I discussed the matter with the Officers of the Institute of Physics and the Club. The upshot was that the Institute continued its support for another year when Scott Blair and Harrison agreed to carry on, with such help as they could get. The Club by then was the proud possessor of a Post Office Account and a rubber stamp, which were used effectively to persuade Miss Mary Milligan, a friend of the Scott Blairs', to do the office work for a very modest fee, but the Institute's duplicator and addressing machine continued to be of service to the Club for a while.

In the 'Reading' days the Club tackled such trying problems as 'Pi,' and the classification of deformations of materials. It may have been a case of 'fools rush in where angels fear to tread,' but we did enjoy ourselves! Exchange of views was frank and free and often I regret to say I felt that the experts knew no more about what was being discussed than I, as Chairman, did—and said so. In view of the later developments, I am not so sure that the old adage 'there is many a true word spoken in jest' is not applicable in this instance!

I hope that Scott Blair and Harrison will add to these notes, and fill in the parts I have missed and modify any exaggerations. They must not fail to say something about the first week-end Conference, when the Scott Blairs were able to re-live the early scenes of their Oxford romance in her old College—St. Hilda's—in which the Conference was held.

H. R. LANG.

[Dr. Harrison and I have nothing to add but we welcome this opportunity of putting on record the very informal way in which the Club had its beginnings, nor shall we forget the debt we all owe to Dr. Lang, and to the Institute of Physics for their invaluable help in the early days of our Club.—EDITOR.]

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 31st March 2014 with successful applicants notified by the end 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

British Society of Rheology

NOTICE of the 73rd Annual General Meeting

The 73rd Annual General Meeting of the British Society of Rheology will be held at the Lake Vyrnwy Hotel, Powys, Wales on Tuesday 15th April 2014 at 5.15pm.

The draft minutes of the 72nd Annual General Meeting are attached to this message.

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

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

Council proposes the following motion for consideration by the AGM.

Resolution: Following the decline in subscriptions to Rheology Abstracts and a majority of support from members through a survey by email, it was announced in Vol 54 No 3 2013 of the Rheology Bulletin that Rheology Abstracts would no longer be published. The post of Abstracts Editor is therefore no longer required. Council proposes to replace this with an officer responsible for the society's website and electronic communication with members. This entails the following changes to the constitution:

* 5(a): replace "Editor (Abstracts)" with "Editor (Web)"

* 8(h): replace "The Editor (Abstracts) shall be responsible for the preparation and circulation of the Society's publication entitled Rheology Abstracts" with "The Editor (Web) shall be responsible for the preparation and posting of material to the Society's website and other online forums"

Council's nominations for Officers and Council members are therefore:

President	Prof. P.R. Williams
Hon. Secretary	Prof. S.J. Cox
Hon. Treasurer	Mr S. Goodyer
Membership Secretary	Dr M. Charalambides
Bulletin Editor	Dr R. Poole
Web Editor	Mr P. Hodder

Ordinary members of Council:

- * Dr B. Dobraszczyk
- * Dr S. Fielding
- * Dr N.E. Hudson
- * Prof. T.N. Phillips
- * Dr M. Tassieri
- * Dr R. Watson

Note that council proposes that Steve Goodyer serve an exceptional fifth year in the absence of any nominations for Honorary Treasurer.

Further nominations for Council or for any of the Offices are invited.

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

Members who cannot attend the AGM are invited to make nominations or approve Council's nominations by email or post to the Honorary Secretary:

Prof. S.J. Cox
Department of Mathematics and Physics
Aberystwyth University
Aberystwyth SY23 3BZ
Email: secretary@bsr.org.uk

BSR Annual Award 2014

Nominations are invited for the BSR Annual Award 2014. Each year the BSR makes an award to an individual in recognition of their contributions to rheology. The criteria for the award focus on the scientific merit of the candidate a person who has made a significant contribution to rheology either through a single paper or more sustained activity. The recipient in 2013 was Jason Stokes, in 2012 Tim Phillips, and in 2011 David James.

Nominations, with a brief supporting statement, should be sent to the President, on president@bsr.org.uk, by the end of May 2014.

Report on BSR Midwinter Meeting 2013

The 2013 midwinter meeting was held at the Institute for Manufacturing at the University of Cambridge on the theme of “Coating Printing and Painting “. There were around 50 attendees including representation from the industrial companies located in the Cambridge area, and a mixture of long-time members and delegates who were new to the BSR. The talks and posters covered theory and experiments on a range of different topics from the extensional rheology and jet break-up to the spreading and drying of drops. It was particularly pleasing to see the quality and range of work presented by PhD students, as well as a more equal gender balance than is usual in physical science and engineering conferences. In the opening keynote talk, Philip Threlfall-Holmes gave an introduction to the rheology of coatings and paints. He stressed that while rheology itself is not a designed function of coatings, it is nevertheless essential to achieving these functions. He went on to set out a number of open research challenges for rheologists from the coatings industry.

The early afternoon session was devoted to extensional flows. First, Malcolm Mackley discussed the challenge of measuring the extensional rheology of low viscosity fluids at the high deformation rates encountered in inkjet printing and described his latest instrument, the “HB4 Trimaster”, a refinement of the filament stretching rheometer that is capable of accessing the extension rates found in inkjet printing. Suzanne Fielding discussed what aspects of the form of the constitutive relation in a complex fluid give rise to the necking instability in complex fluids under uniaxial extension. Finally Claire McIlroy showed how local variations in particle concentration lead to accelerated capillary thinning of particulate solutions. The session ended with a series of “elevator pitches” from poster presenters.

Following the poster session we had three talks on the surface tension and drying of droplets. Emma Talbot showed that watching ink dry is far from boring for particles suspended in solvent mixtures, as the Marangoni forces produce a cycling flow pattern that collects particles at the drop centre, offering a mechanism to overcome the coffee staining effect. Lorenzo Botto showed simulations of the effects of capillary interactions between non-spherical particles absorbed at an interface. Finally Jutta Stauber discussed evaporation kinetics and the subtle relationship between drying time and the nature of the contact line.

The final talk of the day was preceded by the presentation of the Vernon Harrison award to Robyn Cooke for the best PhD thesis on a topic in Rheology. In presenting the award the BSR president, Rhodri Williams noted that this year had seen the highest number of entries for the award, with a very high standard. Robyn

then gave her award lecture exploring theoretical the development of the shear-banding instability in the start-up of shear flow.

The conference dinner was held in Robinson College, the home college of Malcolm Mackley, who generously treated everyone to a glass of college port. He then surprised the all the former BSR presidents by insisting each one give a short impromptu speech about the importance and value of the BSR. Each testified to the openness and friendliness of the BSR,

In the opening talk on Tuesday morning, Rhodri Williams gave a fascinating account of how the microstructure of the fibrin network of blood clots can be characterised by the fractal dimension of their gel networks, which can discriminate normal clotting behaviour from the denser clots that can potentially lead to strokes. This offers the possibility of a future diagnostic test based upon rheological measurement. Jörg Läger then described a new rheometer from Anton Paar, which by using two motors is able to combine the benefits of controlled stress and controlled strain rheometers in a single instrument.

The final three talks returned to the rheology of low viscosity fluids typical of inkjet printing. Colin Bain showed how the linear viscoelastic response and surface tension can be measured from the frequency and decay of drop oscillations. Neil Morrison then discussed how shear and extensional rheology affect drop on demand printing of complex fluids, and how this might be exploited to improve jetting. The closing talk was given by Steve Hoath from the home team, who gave an overview of how polymers and particulates affect drop-on-demand printing and the extent to which this can be predicted from rheological measurements, such as the “Trimaster” experiments described earlier by Malcolm Mackley and rheological models.

Oliver Harlen, Leeds



NON NEWTONIAN CLUB

The Non-Newtonian Club is an informal discussion group which provides low-cost, informal one-day meetings to provide a forum for industrial and academic rheologists to meet together and to present work in progress. A good mix of speakers from industry and academia is the norm and also for research students working on industrially related projects to present their results.

Next meeting:

Rheological Measurements of Food Properties. 22nd May 2014

Rheological Measurements of Food Properties. 22nd May 2014		
Reading Scientific Services Ltd (RSSL), The Science & Technology Centre University of Reading, Earley Gate, Whiteknights Road, Reading RG6 6BZ		
10:15-10:40	Registration & Refreshments	
10:40-11:00	Welcome & introduction to RSSL	
11:00-11:40	Maria Charalambides, Imperial College	Micromechanical modelling of bread dough
11:40-12:00	David White, MDLZ Bournville	Spreading the love: rheological observations of Marmite
12:00-12:40	Dr Ian Wilson Department of Chemical Engineering University of Cambridge	The rheology of food bubbly liquids
12:40-13:30	Lunch	
13:30-14:00	Richard Watson University of Birmingham	Effect of salt reduction on food rheology
14:00-14:30	Ross Winter Imperial College	Bubbly flows in Newtonian and Non-Newtonian liquids
14:30-15:10	Bill Frith Unilever	Some aspects of Aqueous phase structuring and rheology in food and personal care products
15:10-16:10	Tour of RSSL	

* Please inform Bogdan Dobraszczyk if you are planning to attend so we can plan catering and refreshments.

INDUSTRY NEWS

Academic Advantage Program for 2014

Anton Paar are pleased to announce the launch of our Academic Advantage program which entitles institutions providing further education to an array of benefits including :

- Substantial discounts.
- Free installation and on site training
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This program applies to the MCR series of rheometers as well as refractometers, polarimeters and instrumentation for petrochemical analysis. In order to register for this promotion please contact steve.goodyer@anton-paar.com before 30/6/2014.

Anton Paar Acquires CSM Instruments

On November 15, 2013, the purchase contract between Anton Paar GmbH and CSM Instruments SA was signed.

CSM Instruments develops, produces and sells laboratory instruments for the characterization of mechanical properties on material surfaces at the micro- and nano-scales. Products include nanoindentation equipment, tribometers and 3D imaging equipment. Its renowned and globally active customers are found, for example, in academic research, the automobile industry, in the field of environmental technology and in life sciences. CSM Instruments, spin-off of CSEM in 1999 (Centre Suisse d'électronique et de Microtechnique), has been developing instruments for more than 40 years.

Dr. Friedrich Santner, CEO of Anton Paar GmbH: "Both companies have expert knowledge which has been built up over several decades and longstanding experience in the development and manufacture of precise high-tech measuring instruments. We complement each other, for example in the fields of material characterization and tribometry. The acquisition of CSM Instruments results in an excellent extension of our product portfolio."

CONFERENCE & COURSES 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/
14-16 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)
22 May RSSL, University of Reading	NON-NEWTONIAN CLUB Rheological Measurements of Food Properties Conference Contact: Bogdan Dobraszczyk (bogdan.dobraszczyk@rssl.com)
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
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
9 – 10 July Nottingham University, 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



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