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S. G. MASON—A RETROSPECTIVE

T. G. M. VAN DE VEN
Pulp and Paper Research Institute of Canada and Department of Chemistry, McGill University, Montreal, Quebec H3A 2A7, Canada

Without exaggeration one can say that Professor Stanley G. Mason was one of the founders of the science of microrheology. His early interest in this field was aroused when trying to understand the complex behavior of papermaking suspensions, the obvious relevance of which became evident after joining the Pulp and Paper Research Institute of Canada (Paprican) in 1946. Besides his publications with Professor Otto Maass from his thesis work on critical phenomena, his early work deals almost exclusively with the hydrodynamic and colloidal aspects of pulp suspensions. He realized that in order to understand the complexity of such systems, it was necessary to study the properties of the individual pulp fibers that make up the suspension. In this respect the classical work of Jeffery (1922) on the motion of ellipsoidal particles in linear shear flows was extremely relevant. Mason compared a pulp fiber with a long slender spheroid and applied Jeffery's theory to the motion of single suspended fibers. Over the years a large number of papers by Mason and coworkers were devoted to the extensions of Jeffery's work. From this early work came the realization that the properties of suspensions can be understood from a knowledge of the behavior of the suspended particles, a realization which led to the science of microrheology, a term coined first by Mason himself.

Mason's early work on papermaking became classical among scientists working in the field of pulp and paper. It led, among other things, to an understanding of the electrokinetic properties of pulp fibers (Mason 1950b; Goring & Mason 1950; Biefer & Mason 1954), to a widely used method of measuring the specific surface of fibers (Mason 1950a) and to a test of the bursting strength of paper (Faichney & Mason 1952). Most importantly, it led to an understanding of the turbulent diffusion in paper machines (Mason *et al.* 1954) and the flocculation and flow behavior of papermaking suspensions (Mason 1954; Robertson & Mason 1956; Forgacs *et al.* 1958). The publications arising from his early period show the characteristics for which Mason became famous in the field of microrheology: a thorough mathematical analysis together with careful and elegant experimental observations. For these achievements alone Mason deserved a place among the world's great scientists. However, he gained even more fame for his subsequent work.

This early work on papermaking was instrumental in shaping the future developments in Mason's career. He realized from the beginning that the basic principles underlying particle motion in papermaking suspensions could be equally applied to a large number of other fields. As examples we can mention: (i) the work on turbulent diffusion in paper machines, which contained the germs of the modern statistical theory of turbulence and (ii) the motion of pulp fibers, which is similar to the motion of many nonspherical particles in other systems, such as red blood cells in blood flow, clay particles in papermaking coatings and logs floating on rivers. As a result of the many basic insights gained from papermaking research, Mason turned his attention more and more to model systems which could be rigorously described by hydrodynamic theory and observed by cinephotography. Initially he looked at rigid rods (Travelyan & Mason 1951), flexible rods (Forgacs & Mason 1959), droplets (Bartok & Mason 1958; Rumscheidt & Mason 1961a, b) and, of course, spheres (Bartok & Mason 1959). The work on hard spheres is of particular importance since it can be considered the simplest system for which exact results can be obtained. At the same time the motion of a sphere in a shear flow and the fluid flow around it (Cox *et al.* 1968) shows qualitatively similar behavior as more complex systems and serves as the starting point for understanding hydrodynamic particle interactions. The work on spheres is an extension of the early work by Einstein (1906, 1911), who calculated the viscosity of a dilute suspension of spheres. Part of this calculation consisted of calculating the flow field around a sphere in a linear flow field. Curiously, Mason makes no reference to Einstein's early work. Einstein, however, made no comments about the form of the flow field, such as the existence of close streamlines orbiting the sphere.

The discovery of closed streamlines around spheres subjected to a simple shear flow had wide-ranging consequences. It implied that small particles could orbit a large sphere in shear flow and, by extension of these ideas, it led to the realization that all kinds of particles could orbit other particles, due solely to hydrodynamic interactions. Mason was particularly interested in the simple case of the interaction of two identical spheres in shear flow. His first paper on this topic goes back as far as 1952 (Manley & Mason 1952), while his last paper on this topic appeared in 1981 (Adler *et al.* 1981). Various interactions (besides hydrodynamic ones) are included in the analysis, such as the interactions between colloidal electrically charged spheres (van de Ven & Mason 1976, 1977), effects of external electric fields (Arp & Mason 1977a, b), effects of polyelectrolytes (Takamura *et al.* 1979), interactions of spheres connected by flexible rods (Takamura *et al.* 1981), which serve as a model for polymer-bridged doublets, and effects of Brownian motion (van de Ven *et al.* 1981). He also studied the interaction between two drops and their coalescence or (partial) engulfment (Torza & Mason 1970; Mason 1971). Not only were particle interactions studied in dilute systems, but in concentrated systems as well (Karnis *et al.* 1966).

Besides extending the theory of a sphere in a simple shear flow to two-sphere systems, many of Mason's publications deal with extensions of the theory to particles of different shapes, following the early work of Jeffery on ellipsoidal particles. We have already mentioned the work on rigid and flexible rods and drops. Other particles considered were threads and microcapsules. Many papers deal with macroscopic properties of suspensions consisting of such particles, most of which deal with suspensions of noninteracting spheroids. The properties studied were viscosity (Okagawa *et al.* 1974), rheo-optical properties (light scattering, turbidity) (Okagawa & Mason 1977; Cerda *et al.* 1981) and dielectric properties (Okagawa *et al.* 1978), most of them in both the presence and absence of electric fields. In several papers particle interactions were included (Arp & Mason 1977c; Ivanov *et al.* 1982).

The motion of closed streamlines also turned out to be a useful concept in explaining the phenomenon of aggregate or floc break-up. When closed orbits exist, it is difficult to break up aggregates. Even if a particle detaches from a large aggregate, it will not be convected away but stay associated with the floc, orbiting it on a closed trajectory. In the absence of closed streamlines, such as in extensional flow, break-up is much more effective (Kao & Mason 1975; Powell & Mason 1982).

In addition to the work in microrheology, Mason also became interested in the field of wetting and spreading of liquids on solid surfaces. Here again he was spurred by the relevance of this field to applications in papermaking (printing, sizing, absorbency etc). In this area he also showed that complicated phenomena (such as the wetting of a sheet of paper) can be broken down in simpler phenomena which can be studied in detail. Examples are the wetting of various model rough surfaces by several liquids (Huh *et al.* 1975; Huh & Mason 1977), the effect of sharp edges (Oliver *et al.* 1977) and contact angle hysteresis (Huh & Mason 1977; Bayramli *et al.* 1981). Again rigorous theories were developed which were tested with elegant wetting and spreading experiments, with liquids either advancing or receding on a horizontal disk (Mason 1978) or on a vertical probe (Okagawa & Mason 1978; Bayramli *et al.* 1981), a technique which Mason called "capillarography". He also took high-resolution pictures of advancing liquids in a scanning electron microscope, the first pictures of this kind ever produced by this technique (Oliver & Mason 1977).

Last but not least, we want to mention Mason's interest in biological systems, especially blood. Here, as well, he was able to explain several phenomena by studying model systems such as deformable drops in Poiseuille and pulsatile flow (Takano *et al.* 1968), which serve as models for erythrocytes and the irregular motion of single particles in concentrated dispersions, giving rise to apparent Brownian motion and dispersion (Goldsmith & Mason 1967).

In all these diverse fields of interest, papermaking, microrheology, wetting and spreading and biorheology, Mason produced a substantial number of films of dazzling beauty, combining scientific observations with esthetic value. His movies show fascinating motions of all kinds of particles, rotating, colliding, deforming, rupturing, embracing or engulfing. Since Mason rarely gave a seminar without showing a movie, it is no wonder that he was an extremely popular lecturer.

Over his career, Mason supervised some 60 students and 20 postdoctoral fellows with whom he published about 270 papers, most of them after joining Paprican in 1946. Prior to this he obtained his B.Eng. (in 1936) and Ph.D. (in 1939) in chemistry at McGill University under the supervision of Professor Otto Maass. During the war he was a research engineer in the Department of National Defense. While at Paprican he held an honorary cross-appointment in the Department of Chemistry at McGill University, where he was appointed a full professor in 1966, Otto Maass Professor in 1979 and Emeritus Professor in 1985.

Among the many awards he received were the Kendall Award in Colloid Chemistry (1967), the Anselme Payen Award in Cellulose Chemistry (1969), the Bingham Medal in Rheology (1969), the Chemical Institute of Canada Medal (1973), the Dunlop Award (1975), the Howard N. Potts Medal (1980) and, one year before his death, the highest scientific distinction awarded in the Province of Quebec, the Prix Marie-Victorin (1986). When he retired in 1979, a festschrift in his honor was issued [*J. Colloid Interface Sci.* **71** (1979)], which included an appreciation of his work (Goldsmith & Goring 1979). More recently, an issue of *Biorheology* was also dedicated to him [*Biorheology* **26** (1989)], which included an overview of his accomplishments in this field (Goldsmith 1989).

In October 1989 the Society of Rheology held their annual meeting in Montreal, together with the 1st Annual Meeting of the Canadian Rheology Group. Since Mason spent almost all his life in Montreal, it was appropriate that the section on "Multiphase Systems and Biopolymers" be dedicated to him. Several papers in the session on "Microrheology" organized by Professor H. Brenner and myself appear in this issue. A well-deserved tribute to a man who devoted his lifetime to the science of microrheology. His death on 21 April 1987 is still fresh in our memories and his passing evoked a great sense of loss to his many friends, colleagues and students. We hope that his exemplary achievements will continue to be a source of inspiration for many.

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