

Rheology and Mechanics Research

By Roger Tanner

Rheology and Mechanics Research in the School

While Engineers are all necessarily familiar with Mechanics, the branch of that subject called Rheology is not so familiar. Rheology is the generic name given to the study of the flow and deformation of matter. Elasticity and fluid mechanics are sub-branches of rheology, but normally rheological studies concern ‘soft’ materials which behave in a more complex way, for example: rubber; molten plastics; synovial fluid in human joints; foods; detergents; solutions of long-chain molecules in water and many others. Often these materials exhibit both elastic and viscous properties and they behave in a highly non-linear way, which makes their study difficult and interesting. Typical unexpected responses are seen, such as a fluid consisting of a rubber in a solvent which climbs up a rotating rod [Figure 1], or the expansion of an extruded stream of plastic after passing through a die.

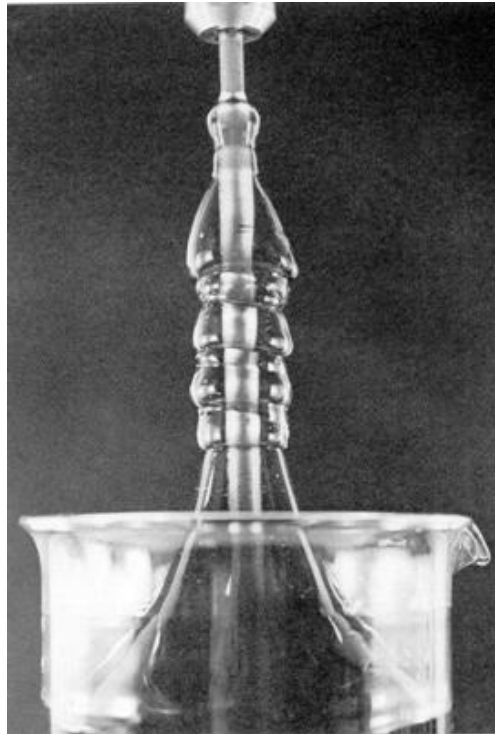


Figure 1 The Weissenberg effect where a solution of plastic in a solvent climbs a rotating rod. Normal viscous fluids do not behave in this way.

From 1963 onwards, forty-two PhD's and eighteen Masters theses have been completed in the Department (see list at the end of this Chapter.) Notable research has been undertaken by Hugh Nelson, Roger Tanner, John Atkinson, Nhan Phan-Thien, Howard See and Ahmad Jabbarzadeh.

A significant development for the study of mechanics was the appointment of Associate Professor H. M. (Hugh) Nelson in 1962, because he was an enthusiast for reforming thinking about the teaching of system dynamics for engineers. Hugh, trained as an electrical engineer in Queen's University, Belfast, was an excellent source of knowledge on systems engineering and instrumentation. He had worked in the research laboratories of the General Electric Company in England for seven years. Soon after that he joined the Aeronautical Research laboratories at Fisherman's Bend in Victoria, and was in charge of the Instrumentation Group. After he came to the University of Sydney, this experience was very useful to other members of the Department. For example, he assisted John Simmons in his measurements of rheological properties in the early 1960s. Somewhat of a perfectionist, his research output was relatively small, but his influence on mechanics teaching was significant. He died in 2001.

In 1960 Roger Tanner was working on lubrication at Manchester University when he was led into the study of rheology, because most motor oils are not simple viscous fluids, but show some elasticity. Then he became interested in the mathematical description of such materials in his first sojourn as Senior Lecturer and then Reader in Sydney (1961-1966). Notable students were J. W. (Jim) Hayes (B.E. 1960, M.Sc. 1963), J. M. (John) Simmons FTSE (B.E. 1962, PhD 1967), and R. R. (Raj) Huilgol (PhD 1968).

Two of these students went on to distinguished academic careers: John Simmons FTSE (BE 1962, PhD 1967) became Dean of Engineering at the University of Queensland, and Raj Huilgol (PhD 1968) is a Professor of Mathematics at Flinders University. Some other distinguished careers were followed by Mark Bush FTSE (PhD 1983, Professor and Dean of Engineering at the University of Western Australia), and A. M. (Tony) Johnston (PhD 1980), whose PhD research enabled him to found the Heatric company.

John Atkinson (1940-2011) was an extremely able but eccentric member of staff. Awarded the Mechanical Engineering University Medal in 1962 and subsequently the Charles Kolling Travelling Scholarship from Sydney University, he went to the California Institute of Technology (Caltech) in Pasadena to study for a PhD. He worked with Professor Tom Caughey on randomly excited dynamical systems and Caughey once said that Atkinson was his best student ever. After the PhD, John returned to the Department in mid-1967 and was subsequently promoted to Senior Lecturer in 1977. He was never promoted further, despite his good teaching, research and administrative activities, perhaps because he clammed up during interviews.

John collaborated well and widely in research, not only with the rheology group, but also with R. A. (Bob) Antonia, R. E. (Sam) Luxton, Bob Bilger, Roy Henderson and of course Tom Caughey. His office was in apparent disorder, with paper everywhere and the phone underneath, but John knew where things were. He was kind to the less able: he successfully supervised two PhD candidates who had been abandoned by their original supervisors in fits of frustration. Physically strong, he was a keen bushwalker. Sadly, he drowned while swimming in very rough seas near his home in May 2011. His funeral and a Memorial Service at St. Paul's College were attended by hundreds of colleagues, friends and relatives.

Roger Tanner became interested in plastics extrusion and polymer processing generally while at Brown University in the USA. These activities led to a consultancy with Dupont in Wilmington, Delaware. He continued to work in these fields in Sydney after his appointment in Sydney as P. N. Russell Professor in 1975.

When he arrived back in Sydney in July that year, Roger Tanner had already submitted two ARC grant applications: one for computational fluid mechanics work on extrusion and the other for experimental rheology. Both grants began in 1976. By great good luck, Nhan Phan-Thien signed up to do a PhD with the group.

Nhan Phan-Thien was born 31 October 1952 in Vietnam. He came to Australia for university study as a Colombo Plan student and in 1975 he was the Department's University Medallist. During his undergraduate days Nhan had written his name in the Asian style as P. T. Nhan, which is engraved on his University Medal. He completed an excellent PhD thesis on a model for polymer rheology in less than three years and the thesis had to be submitted with instructions that it should not be opened until September 1, 1978, as the University required a minimum of six semesters of registration for the PhD.

Upon receipt of his PhD in 1978, Nhan took the rheology group (plus Dr. Yiu-Wing Mai, as he then was) out to a Vietnamese restaurant in Sydney for a 'steamboat' dinner. After dinner Nhan said that the area was too quiet ('like a Sunday School') and he led the group off to King's Cross. We went into a fairly sleazy place in Darlinghurst Road where there was a show running and which had advertisements outside like "We've nothing on tonight!" and "Here the belles peel!". No alcohol was served, only poor coffee and, even worse, orange Fanta. Roger watched the show until 11pm and then went home. Apparently the rest of the group stayed to see the show again, until 2am!

Nhan went to Newcastle University as Lecturer in Mechanical Engineering in 1978. He returned to Sydney as Lecturer in 1980. A long collaboration then ensued between him, Roger Tanner, and John Atkinson, who had become interested in rheology because of his expertise in randomly excited nonlinear systems.

Nhan was promoted to Senior Lecturer in 1983 and won the Royal Society of New South Wales's Edgworth David Medal in the same year. He was promoted to Reader in 1986, and was the holder of a Personal Chair from 1991 until 2000. He was most proud of the Gordon Bell prize, which he won in 1997. This prize was typically won by major US National Laboratories, but for that year, was awarded to an entry from Sydney University (Nhan Phan-Thien, David Tullock and Ka Yan Lee) for a distributed computing algorithm dealing with suspensions.

Nhan was made a Fellow of the Australian Academy of Science (FAA) in 1999, but he moved to the National University of Singapore in 2000. This departure was possibly partly influenced by the then Dean. There was no mutual respect between them: Nhan's prime interest was research and the Dean was not so interested in that activity.

For his contribution to Mechanical Engineering, Nhan was awarded the Centenary Medal in 2001. The model of polymer rheology, the so-called Phan-Thien-Tanner (PTT model) has been widely cited and used in industry and in academia, in part because of its simplicity.

Nhan's career took an unexpected turn in 2004 when he left Singapore and went to California to work in a company that developed shopping malls. He returned to the University of Singapore in June 2011 as Professor after developing five shopping centres!

Nhan had one son and two daughters by his first wife (Lai Kuen). He has since remarried, to Kim Thoa, who was his high school sweetheart back in his Vietnam days. They are based on the Sacramento River in California, but currently are living in Singapore.

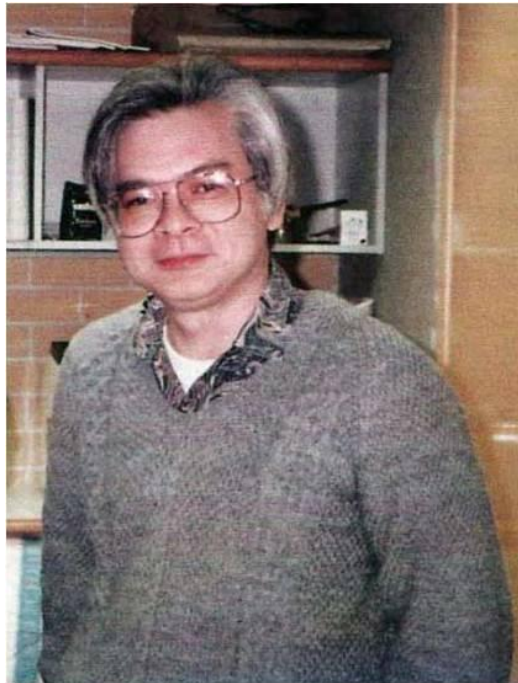


Figure 2 Nhan Phan-Thien in 1999.

In 1980, the same year that Nhan Phan-Thien had returned to Sydney University, Howard See was the Department's University Medal winner. After graduating, Howard went to Japan to do a PhD with Professor Masao Doi. He was a fluent Japanese speaker, and he worked in research with the Bridgestone Company in Japan after his PhD studies. Howard came back to Sydney University where he joined the Rheology group as a University Postdoctoral Fellow in 1990. After the completion of his Sydney Postdoctoral appointment, he became a Senior Lecturer and then Associate Professor in the Chemical Engineering school, where he continued his prolific rheological research. Tragically, he died of heart failure in early 2010; around five hundred people came to his memorial service at St. Paul's College Chapel.



Figure 3 The organizers of the 2009 Korea-Australia Rheology Conference in Sydney - Howard See, Roger Tanner and Ahmad Jabbarzadeh - on a Harbour Cruise. The Rheology group were also responsible for hosting the 1988 International Congress on Rheology and the 1998 International Union of Theoretical and Applied Mechanics (IUTAM) meeting.

In 1994 the rheology group became involved in an ARC Linkage Grant on injection moulding research with the Moldflow Company in Melbourne. This association later turned into a twelve year research collaboration (1999-2011) via the Polymer Cooperative Research Centre. The association has just culminated in the publication of a book on injection moulding (Springer-Verlag Berlin 2011) by Rong Zheng, Roger Tanner and Xijun Fan.

Zheng was Roger Tanner's PhD student in 1991 and then was for sixteen years a Moldflow employee in Melbourne. He is now an Adjunct Associate Professor in our School. Co-author Xijun Fan is another PhD student of Roger's who graduated in 2006. Xijun Fan is now retired, but is still active as an Honorary Associate.

A new development into micro/nanomechanics was made from 1994 onwards by group member Ahmad Jabbarzadeh, who received his PhD in 1998, and who has been a Senior Lecturer in the School since 2007. Ahmad has studied polymer crystallization and tribology (the collective name for studies in lubrication, friction and wear) using non-equilibrium molecular dynamics methods. This is a very large-scale computing exercise at the micro-nano mechanics level.

Other long-term group members have included: Yurun Fan (now back in China as Professor at Zheijiang University); Shicheng Xue (PhD 1997), now working separately; and Matti Keentok (PhD 1998), now retired after working at Penrith with the Defence forces. Group members Shaocong Dai (PhD 2002) and Fuzhong Qi (PhD 2000) are still with us.

Trevor Sutton was a longstanding and valuable technical staff member. He was devolved to us from the Mechanical Engineering workshop and he served us very well in the laboratory. He worked for about ten years in the Engineering General Workshop, and about twenty years in Mechanical Engineering, retiring in 2006. Trevor could see what needed to be done very quickly, despite sometimes being given misleading input from academics. He was very efficient, energetic and independent; he enjoyed tennis, and to a lesser extent, golf. We miss him.

The group was also involved with research on bread dough rheology through the Quality Wheat Cooperative Research Centre (1994-2000). This work continues with ARC support, and through the efforts of Dr. Surjani Uthayakumaran (PhD Agriculture 1999), it links the Agriculture and Engineering faculties.

Our continuing projects include flow-induced crystallization in polymers in injection moulding, tribology of thin films of lubricants, bread dough rheology, and the mechanics of suspensions of particles with non-Newtonian fluid matrices. The group is now smaller than that shown below, but Rheology is still fascinating, and we believe that the rather rare application of a Mechanical (as opposed to a Chemical) Engineering approach to the subject has been fruitful.



Figure 4 Rheology Group 1999

Front Row: Lyn Kennedy (Administrative Assistant for Group), Nhan Phan-Thien, Roger Tanner, John Atkinson.

Standing: Clint Joung (PhD 2003), Prof Xijun Fan (PhD 2006), Marcus Newberry, (PhD 2003), Zhizen Liu (PhD 2001), Matti Keentok (PhD 1997), Mr Taisir Hubraq, Ms. Ping Jiang, Dr. Ferenc Bekes (CSIRO), Surjani Uthayakumaran (PhD Agriculture 1999), Simin Nasser (PhD 1997), Dr. Peter Gras (CSIRO), Fuzhong Qi (PhD 2000), Prof. Yurun Fan, Assoc. Prof Howard See, Babatunde Fasheun (M.Sc 2000). At the time this photo was taken many of the group were actually still studying for their degrees.

References

A. Atkinson (2011) *Man of letters and idiosyncracies*. Sydney Morning Herald, June 5.

Rheology Group Higher Degrees (in alphabetical order of surname)

PhD Degree List

Aaron Avagliano (1998)
Philip Bendeich (2002)
Erwan Bertevas (2011)
Craig Beverly (1992)
Mark Bush (1983)
Xijun Fan (2006)
Zhiwu Fang (1997)
John Field (1995)
Robert Fleet (1983)
Ba Phoc Huynh (1980)
Rajah Huilgol (1968)
Vic Ilic (1994)
Ahmad Jabbarzadeh (1997)
Anthony Johnston (1980)
Clint Joung (2003)
Matti Keentok (1997)
Masud Khan (1989)
Seong Jae Lee (1993)
Duane Lee Wo (2010)
George Liang (2006)
Yang Liu (1997)
Stephen Lucas (1993)
Xiaolin Luo (1987)
Enn Mannik (1993)
Ramin Mohajeri (1998)
Simin Nasser (1997)
Marcus Newberry (2003)
Nhan Phan-Thien (1978)
Fuzhong Qi (2000)
Marcel Ramia (1993)
Roland Schmid (1986)
John Simmons (1967)
Junsuo Sun (1995)
Thanh Tran-Cong (1989)
David Tullock (1993)

Jonathan Vincent (1996)
William Walsh (1986)
Shicheng Xue (1997)
Zhaosheng Yu (2003)
Antony Zdilar (1994)
Rong Zheng (1991)
Xian Zhou (1991)

Master's Degrees

M. Ahmad (1994)
Harry Bate (1968)
Milton Behrendorff (1980)
Marco Breakenridge (1982)
J. J. Cheng (1987)
Babatunde Fasheun (2000)
Hopetoun Gray (1985)
Jim Hayes (1963)
Vangu Kitoko (2003)
Peter Krüsi (1984)
Ian Linnett (1968)
Alex Morales-Patino (1997)
Anthony Powell (1995)
A. A. Mansy (1977)
Graham McBride (1986)
Stilianos Rafailidis (1984)
Peter Tuft (1989)
Ken Waldron (1966)