WCCE9
APCChE 2013

www.wcce9.org

WCCE9 & APCChE 2013

9th World Congress of Chemical Engineering

Incorporating 15th Asian Pacific Confederation of Chemical Engineering Congress

August 18-23, 2013 / Coex, Seoul, Korea

"Chemical Engineering : Key to the Future"

Hosted by KIChE Under the auspices of WCEC

AUSTRALIAN SOCIETY OF RHEOLOGY

HOWARD SEE YOUNG RHEOLOGIST TRAVEL AWARD 2012 – CONFERENCE REVIEW

Recipient: Hui-En Teo

Conference: 9th World Congress of Chemical Engineering (WCCE9)

Location: Seoul, South Korea

Dates: 18 – 23 August, 2013

OVERVIEW

This review covers my participation in the 9th World Congress of Chemical Engineering, a laboratory visit to the School of Chemical and Biological Engineering (Lab of Microrheology) at Seoul National University (SNU) and a laboratory visit to the Division of Chemical and Biomolecular Engineering at Pusan National University (PNU). This trip would have not been made possible without the generous support of the Australian Society of Rheology (ASR) through the inaugural Howard See Young Rheologist Travel Award (2012).

TIMELINE

Date	Activity	Location
17 Aug 2013	Travel from Melbourne, Australia to Seoul, South Korea	Melbourne, Australia
18-23 Aug 2013	WCCE9 Conference	COEX, Seoul, South Korea
26-30 Aug 2013	SNU Laboratory Visit	Seoul National University, Seoul, South Korea
2-6 Sept 2013	PNU Laboratory Visit	Pusan National University, Busan, South Korea
8 Sept 2013	Travel from Seoul, South Korea to Melbourne, Australia	Seoul, South Korea

WCCE9

Background

The World Congress of Chemical Engineering conferences are traditionally a joint activity of the following confederations:

APCChE – Asian Pacific Confederation of Chemical Engineers
EFCE – European Federation of Chemical Engineering
IACCE – InterAmerican Confederation of Chemical Engineering

The world congress takes place alternatively in one of the three regions, every 4 to 5 years. In 2013, the 9th World Congress of Chemical Engineering (WCCE9) was held in Seoul, Korea from August 18 to 23. The Congress, on that occasion, also served as the 15th Asian Pacific Confederation of Chemical Engineering Congress (APCChE2013). The central theme of WCCE9 was “Chemical Engineering: Key to the Future”.

The scientific program provided an opportunity for participants to exchange new ideas and information on many important issues in chemical engineering. High-standard plenary and keynote lectures were provided by noted intellectuals both from academia and industry. The Congress was an occasion for participants to make new acquaintances and strengthen existing friendships.

Technical Highlights

Due to the broad nature of the world congress, the presentations and posters were divided across 6 unique topics:

1. Fundamentals in Chemical Engineering
2. Sustainable Development for Future Society
3. Research based on Emerging Technologies
4. Progress in Current Chemical Technologies
5. Promotion of University-Industry Cooperation
6. Chemical Engineering Education

The area of research I presented in was within Topic 1, under the sub-topic, ‘Rheology’. Nonetheless, I enjoyed attending oral presentations within other topics such as pertaining to Chemical Engineering education. Interesting presentations were given by Elspeth Ritchie, Matthew Abbott, Chelsea Brain and Charlotte Bell from Newcastle University in the United Kingdom. In their presentations they discussed the concept and application of an engineering doctorate, distinct from a traditional PhD research program in that the research

engineer engages with university and industry in a 3.5 year industry placement. Engineering doctorates are tasked to solve industrial challenges encountered outside university laboratories, combining the fundamental approach of university research with the practicality demanded in industry. Participants are likely to receive training within sponsor companies and to be offered a position within the research division of said company upon graduation.

Within Rheology, there was a whole suite of thought-provoking presentations, largely from Korean and Australian delegates, with a couple from Japan and the United States:

Ayoung Lee (SNU) - Focussed on optimising experimental parameters to determine jetting regimes in piezo- and electro-hydrodynamic inkjet printings.

Woojoo Han (SNU) – Used in-situ flow visualisation techniques in capillary flow to characterise flow instability of concentrated particulate suspensions.

Heekyoung Kang (SNU) – Analysed the rheology of colloidal gels in shear flow and reported the local dynamics of fast and slow colloids after high rate stepped strains. Utilised the theory of Potanin et al. to suggest two types of network bonding and that yielding of gels was caused by breakage of weak bonding (fast colloids), while the network of slow colloids determined the microstructure and rheology of yielded colloidal gels (*G'*, using the localisation length of slow colloids, matched *G(t)* in the bulk suspension under small strains).

Prof. Yee Kwong Leong (University of Western Australia, Australia) – Presented results on the yield stress behaviour of bentonite and laponite gels (2:1 swelling clays) including their salt, aging and volume fraction effects.

Assist Prof. Ruri Hidema (Kobe University, Japan) – Analysed the drag reduction effects due to the extensional viscosity of polymers by a two-dimensional turbulent flow method.

Girish Ganjyal (Pepsico Advanced Research, United States) – Focussed on the process engineering of extruded food products taking into account commercial viability and food quality. Utilised a novel supercritical CO_2 extrusion process to enable direct manufacture of superior products because of benefits derived from lowered exit temperatures (< 100˚C).

My Presentation

There were approximately 30 people in the room when I presented. I started off by thanking the ASR for their gracious funding in allowing me to present at WCCE9 and also paid tribute to Howard See's life. Subsequently, I presented my research on the rheology of suspensions under combined shear and compressive loads based on a model calcium carbonate (calcite)

system in water with trace electrolytes. The summary of my talk was as follows:

- Most rheological work through to application has concentrated on pure shear or compression, with little progression into multi-dimensional combinations of both forces
- Stepped strain rate and controlled strain rate stress relaxation tests in shear rheometry can be modified to understand two-dimensional combined shear and compression. This is achieved by loading a rheometer sample cup with a sintered disc and dead weights.
- Before a critical yield strain of ca. 0.1, compression enables shortened relaxation times in stress relaxation; past the yield strain, higher maximum stresses are observed in compression.

The presentation of my findings appeared to be well-received. I completed the talk within 15 minutes, and 5 minutes were allowed for questions. The first question came from Prof. Hiroshi Suzuki of Kobe University, who disclosed that he knew Howard See personally and was happy that the memory of his friend was being honoured through this travel award. He asked about the particle dimension, polydispersity and sphericity of the calcite sample I was using. I responded that the calcite particles were soft spheres and in the colloidal region (ca. 4 μm). Under natural pH conditions they tended to coagulate into aggregates and as a result appeared to be quite polydispersed due to the aggregate clusters of varying sizes.

The second question I received was regarding the authenticity of data when using the novel set-up of dead weights and a sintered disc on a rheometer cup to effect a compressive load. I replied by affirming that due diligence was taken such as an acrylic sleeve tapered onto the sample cup and sufficient bore hole sizes within the centre of the disc and weights to allow the vane to measure torque uninterrupted during shear.

After my talk was over, I received compliments from Elspeth Ritchie and Prof. Sandra Kentish that the presentation was clear, coherent and engaging.

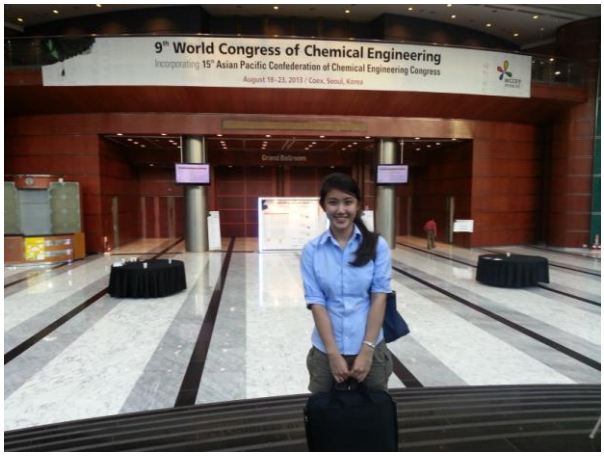


Figure 1A (left): At the main hall area of WCCE9

Figure 1B (right): At the Rheology conference session

Networking

It was fun chatting with researchers from within the rheological field as well as something entirely different like Chemical Engineering Education. I treasured opportunities to build on existing friendships with Prof. Kyung Hyun Ahn and meet his students Ayoung Lee, Woojoo Han (who did a 6 month research collaboration at the University of Melbourne with Prof. Peter Scales) and Heekyoung Kang. I also got to know Prof Yee Kwong Leong, who did his Ph.D. in the University of Melbourne and engineering doctoral students from Newcastle University, whom I still keep in contact with. The world congress experience in Seoul opened my eyes to the big picture of how chemical engineering innovation can push boundaries and solve critical problems happening around the world.

Figure 2: Engineering doctoral students from the UK that presented on Chemical Engineering Education

Seoul National University Visit

Following the conclusion of WCCE9, I visited the laboratory of Prof. Kyung Hyun Ahn and Prof. Seung Jong Lee at SNU, which is called the Laboratory for rheology and processing of microstructured materials. I was there for a week to gain a better understanding of the different laboratory equipment that was used and what types of samples they were testing. Their field of research is mainly focussed on extending rheological findings on polymers and their nanocomposites, including ink and paint. I am grateful to Sang-Hoon and John, Prof. Ahn's students, for showing me around the laboratory and explaining what type of rheometric equipment was present, and for including me in the social activities of their research group. I thoroughly enjoyed my time at SNU.

Figure 3A (left): SNU Chemical Engineering Entrance

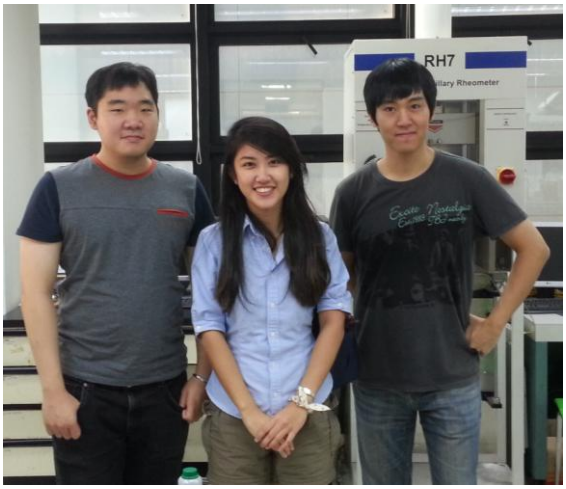


Figure 3B (right): Researchers in Prof. Ahn's group

Pusan National University Visit

At PNU, I caught up with Prof. Kyu Hyun, whose students showed me around their laboratory space and explained to me how to use their equipment. Of interest to me was their ARES-G2, which is an upgrade of the ARES (Advanced Rheometric Expansion System) that I have been using for my rheometric testing. Prof. Hyun is a noted expert in large amplitude oscillatory strain (LAOS) tests and how to analyse them using Fourier transform (FT) rheology. I was very fortunate to be able to chat with him in order to understand the implications of LAOS data and how to discern instrument or material artefacts that give rise to even harmonics, which was present in my LAOS data on calcite. Prof. Hyun and his students were hospitable and generous with their time, inviting me to try out different types of Korean food and also to attend their lectures. It was a pleasure to meet with them – I felt right at home!

Figure 4A (left): PNU laboratory space

Figure 4B (right): ARES-G2 used in Prof. Kyu Hyun's laboratory

Figure 5A (left): Prof. Kyu Hyun's research group

Figure 5B (right): Prof. Kyu Hyun

Summary

Travelling to Seoul to attend a world congress conference and subsequent visits to Korean research institutes opened my eyes to a variety of cultures and backgrounds in a research setting. I relished the experience of being in a different laboratory and learnt much more about the Korean culture through distinguished Korean researchers such as Prof. Ahn and Prof. Hyun. I would like to thank the ASR again for giving me this opportunity to travel to Korea through the Howard See Young Rheologist Travel Award. I would recommend any young rheologist in Australia who is keen to advance their research career and establish/strengthen international research collaboration to consider taking on this experience.

INFORMATION

SESSION CODE

Mo O – T1 01

Day	Presentation Type	Topic	Session Title
-Mo	- PL: Plenary Lecture	-T1	-Topic 1: 32 sessions
-Tu	- SS: Special Session	-T2	-Topic 2: 24 sessions
-We	- O: Oral	-T3	-Topic 3: 13 sessions
-Th	- P: Poster	-T4	-Topic 4: 15 sessions
-Fr		-T5	-Topic 5: 7 sessions
		-T6	-Topic 6: 5 sessions

SCIENTIFIC TOPICS & SESSION TITLES

ORAL

No.	Topics & Session Titles
	Topic 1. Fundamentals in Chemical Engineering
1	Adsorption
2	Bioprocesses
3	Bioreactor
4	Catalysis
5	Catalysis in Polymer Reaction Engineering
6	Chemical Engineering as a Node for Translational Science
7	Chemical Engineering in Colloids Research
8	Coating and Drying Process
9	Computational Fluid Dynamics
10	Dual Bed Fuel Conversion: Fundamentals and Technologies
11	Fluid Mechanics
12	Fundamentals of Process Systems Engineering I & II
13	Gas Hydrates
14	Heat and Mass Transport
15	Materials Synthesis
16	Membrane Separation
17	Microfluidics
18	Microreactor
19	Modeling & Simulation
20	Monitoring Biological Reactions and Processes: Nano, Micro, and Beyond
21	Multiphase Flow Reactors and Contactors
22	New Directions in Reaction Engineering
23	Phase Equlibrium
24	Polymerization
25	Process: Fundamental
26	Reaction Engineering for Energy and the Environment
27	Reaction Engineering for Nanoparticles and Thin Films
28	Recent Research Trend in Petroleum Displacement Technologies
29	Rheology
30	Separation: Fundamental
31	Supercritical Fluid Technology
32	Thermophysics
	Topic 2. Sustainable Development for Future Society
1	Bio- and Biomedical Technology – Yonsei ChE Global Network Forum
2	Bio-fuel
3	Biorefinery
4	Conversion of Carbon Dioxide
5	Current Issue for Automotive Emission Control by Catalytic Technology
6	Energy Efficiency Enhancements in Chemical Processes - Celebrating the 50th Anniversary of Department of Chemical & Biological Engineering, Korea University
7	Fuel Cell: Catalytic Hydrogen Prodcution
8	Fuel Cell: System
9	Gasifier
10	Hydrogen Production from Biomass
11	Ion Exchange Membranes for Sustainable Water and Energy
12	Membrane-based Advanced Water Treatment
13	Membranes for Sustainable Technologies
14	Microalgae-based Biofuels and Bioproducts
15	Multicolumn Continuous Chromatography
16	Multifunctional Smart Materials
17	Novel Separation Technologies for Clean Energy
18	Organic and Inorganic Materials for Energy and Environment I, II– Yonsei ChE Global Network Forum
19	Photovoltaics
20	Process and Technology for Energy and Environment I, II – Yonsei ChE Global Network Forum
21	Sequestration of Carbon Dioxide
22	Shape-Dependent Catalysis: Experiment and Simulation
23	Sustainable Energy
24	Wastewater & Water Treatment
	Topic 3. Research based on Emerging Technologies
1	Advanced Technology for Materials
2	Bio-Inspired & Biomimetic Material
3	Biomedical Applications
4	Biotechnology for Future Chemical Industry
5	Carbon-based Materials
6	Emerging Materials and Technologies in Polymer Electrolyte Membranes for Fuel Cell Application
7	Emerging Polymers in Biomaterials, Bioinspiration, and Biomimetics
8	Energy Conversion and Storage
9	Functional Membranes
10	Functional Thin Films
11	Nanomaterials & Nanotechnology
12	Nanostructured Materials for Chemical Engineering Processes - Celebrating the 50th Anniversary of Department of Chemical & Biological Engineering, Korea University
13	Next-Generation Polymer Based Solar Cells
	Topic 4. Progress in Current Chemical Technologies
1	Applications to Energy Systems
2	Control and Optimization of Chemical Batch Processes
3	Economics and Sustainability
4	Energy System Optimization and Control
5	Micro-nano System Modeling and Simulations
6	Novel Processing Technologies
7	Practice of Safety in Industry
8	Process Control
9	Process Design and Intensification
10	Process Modeling
11	Process Optimization
12	Sustainable Process-Product Design I & II
13	Sustainable Supply Chain Design and Operation
14	Systems Informatics for Virtual Sensing and Process Monitoring
15	Technology and Culture for Process Safety
	Topic 5. Promotion of University-Industry Cooperation
1	Advances in Crystallization Technology
2	Chemical Reaction Technology
3	Crystallization Technology
4	Pharmaceuticals, Diagnostics, and Convergence

INFORMATION

5	Promotion of Public Research Institute-university-industry Cooperation
6	Promotion of University-industry Cooperation
7	Separation Technology

Topic 6. Chemical Engineering Education

1	Chemical Engineering Curriculum Development
2	New Education Paradigm for the 21st Century
3	Outcome Assessments
4	Recruiting and Retention
5	Teaching Pedagogy

POSTER

No.	Topics & Session Titles
Topic 1. Fundamentals in Chemical Engineering	
1	Adsorption
2	Bioengineering
3	Catalysis
4	Combustion
5	Computational Fluid Dynamics
6	Crystallization
7	Enzyme Reaction
8	Fluid Mechanics
9	Heat Transfer
10	Mass Transfer
11	Mathematical Modeling
12	Membrane
13	Microreactor
14	Mixing
15	Multiphase Flow
16	Polymerization
17	Process Optimization
18	Reaction Kinetics
19	Rheology
20	Separation: Fundamental
21	Supercritical Fluid
22	Thermodynamics
Topic 2. Sustainable Development for Future Society	
1	Battery
2	Bio-fuel
3	Biorefinery
4	Clean Fossil Fuel
5	Conversion of Carbon Dioxide
6	Fuel Cell
7	Green House Gas Capture
8	Metarial Synthesis
9	Multifunctional Smart Materials
10	Solar Energy
11	Sustainability Assessment
12	Wastewater & Water Treatment
Topic 3. Research based on Emerging Technologies	
1	Bio-Inspired & Biomimetic Material
2	Biomedical Applications
3	Carbon-Based Materials
4	Drug Delivery Systems
5	Energy Conversion and Storage
6	Functional Membranes
7	Metabolic Engineering
8	Microreactor
9	Molecular Dynamics Simulations
10	Nano- or Biosensors
11	Nanomaterials and Processing
12	Novel Processing Technology
13	Self- or Directed Assembly
14	Solar Cell
15	Surface and Interfaces
11	Nanomaterials and Processing
Topic 4. Progress in Current Chemical Technologies	
1	Applications to Biomedical Systems
2	Economics and Sustainability
3	Nanocomposites
4	New Materials / Products
5	Novel Applications to Energy Systems
6	Novel Applications to Materials Processing
7	Novel Processing Technologies
8	Practice of Safety in Industry
9	Process Control
10	Process Design and Intensification
11	Process Modeling
12	Process Operation
13	Process Optimization
Topic 5. Promotion of University-Industry Cooperation	
1	Chemical Reaction Technology
2	Crystallization Technology
3	Process Technology
4	Strategy
Topic 6. Chemical Engineering Education	
1	Chemical Engineering Education

DAILY PROGRAM

Aug. 18 (Sun) / **19** (Mon)

Aug. 18 (Sun)	Grand Ballroom (1F)
18:30-20:00	**Welcome Reception**

Aug. 19 (Mon)	Grand Ballroom (1F)					Asem Hall (2F)				Auditorium (3F)			Hall E (3F)			
	101	102	103	104	105	203A	203B	208A	208B	Auditorium	Room 1	Room 2	E1	E2	E3	E4
07:50-08:30	**Opening Ceremony** (Auditorium, 3F)															
08:30-09:20	**MoPL-01. Game Changing Chemical Engineering for Our Sustainable Future** **R.A. Mashelkar, India** (Auditorium, 3F)															
09:20-10:10	**MoPL-02. Sustainable Chemical Engineering: Opportunities and Challenges** **Adisa Azapagic, UK** (Auditorium, 3F)															
10:10-10:30	Coffee Break															
10:30-11:30 / 11:30-12:30	**MoO-T216A** Multifunctional Smart Materials	**MoO-T219A** Photovoltaics	**MoPL-GLS-1** **MoO-GLSA1** GLS-11	**MoO-T112A** Fundamentals of Process Systems Engineering I – In memory of Professor David M. Himmelblau (1924-2011)	**MoO-T215** Multicolumn Continuous Chromatography	**MoO-T131A** Supercritical Fluid Technology	**MoO-T406A** Novel Processing Technologies	**MoO-T121A** Multiphase Flow Reactors and Contactors I	**MoO-T120** Monitoring Biological Reactions and Processes: Nano, Micro, and Beyond		**MoO-T124** Polymerization	**MoO-T106** Chemical Engineering as a Node for Translational Science	**MoO-T217** Novel Separation Technologies for Clean Energy	**MoO-T223** Sustainable Energy	**MoO-T307** Emerging Polymers in Biomaterials, Bioinspiration, and Biomimetics	**MoO-T501** Advances in Crystallization Technology
12:30-14:00	**Lunch**															
14:00-15:00 / 15:00-16:00	**MoO-T216B** Multifunctional Smart Materials	**MoO-T219B** Photovoltaics	**MoPL-GLS-2** **MoO-GLSE1** GLS-11	**MoO-T112B** Fundamentals of Process Systems Engineering II	**MoO-T201** Bio- and Biomedical Technology – Yonsei ChE Global Network Forum (14:00-16:20)	**MoO-T131B** Supercritical Fluid Technology (14:00-16:20)	**MoO-T409A** Process Design and Intensification	**MoO-T121B** Multiphase Flow Reactors and Contactors II	**MoO-T603** Outcome Assessments		**MoO-T103A** Bioreactor	**MoO-T108** Coating and Drying Process	**MoO-T211A** Ion Exchange Membranes for Sustainable Water and Energy	**MoO-T505** Promotion of Public Research Institute-University-Industry Cooperation	**MoO-T206** Energy Efficiency Enhancements in Chemical Processes - Celebrating the 50th Anniversary of Department of Chemical & Biological Engineering, Korea University	**MoO-T506A** Promotion of University-Industry Cooperation
16:00-16:30	Coffee Break															
16:30-17:30	**MoO-T216C** Multifunctional Smart Materials	**MoO-T204** Conversion of Carbon Dioxide	**MoO-GLSD1** **MoO-GLSF1** GLS-11	**MoO-T202** Bio-fuel		**MoO-T131C** Supercritical Fluid Technology (16:30-17:50)	**MoO-T409B** Process Design and Intensification	**MoO-T121C** Multiphase Flow Reactors and Contactors III (16:30~18:10)	**MoO-T102** Bioprocesses		**MoO-T103B** Bioreactor	**MoO-T503** Crystallization Technology	**MoO-T211B** Ion Exchange Membranes for Sustainable Water and Energy	**MoO-T130** Separation: Fundamental	**MoO-T406B** Novel Processing Technologies (16:30-17:50)	**MoO-T506B** Promotion of University-Industry Cooperation
17:30-19:00	**Poster Presentation**															

CODE ABBREVIATION

Mo O – T1 01

- Mo — Day
- O — Presentation Type
- T1 — Topic
- 01 — Session Title

DAILY PROGRAM

Aug. 20 (Tue)

Aug. 20 (Tue)	Grand Ballroom (1F)					Asem Hall (2F)			Auditorium (3F)			Hall E (3F)			
	101	102	103	104	105	203	208A	208B	Auditorium	Room 1	Room 2	E1	E2	E3	E4
08:15-08:25	**Morning Meditation Time** (Auditorium, 3F)														
08:30-09:20	**TuPL-01. Co-Opetition, Co-Innovation and the Role of Academic Research** **Philippe A. Tanguy, France** (Auditorium, 3F)														
09:20-10:10	**TuPL-02. Beyond the Limits to Growth - New Ideas for Sustainability from Japan** **Hiroshi Komiyama, Japan** (Auditorium, 3F)														
10:10-10:30	Coffee Break														
10:30-11:30 11:30-12:30	**TuO-T216A** Multifunctional Smart Materials	**TuO-T219A** Photovoltaics	**MoPL-GLS-3** **TuO-GLSA2** GLS-11	**TuO-T301** Advanced Technology for Materials	**TuO-T218** Organic and Inorganic Materials for Energy and Environment II – Yonsei ChE Global Network Forum	**TuO-T602A** New Education Paradigm for the 21st Century	**TuO-T125** Process: Fundamental	**TuO-T601** Chemical Engineering Curriculum Development	**TuO-AP01** APCBM 2013	**TuO-T504** Pharmaceuticals, Diagnostics, and Convergence	**TuO-T212** Membrane-based Advanced Water Treatment	**TuO-T205A** Current Issue for Automotive Emission Control Catalytic Technology	**TuO-T122** New Directions in Reaction Engineering	**TuO-T213A** Membranes for Sustainable Technologies	**TuO-T110A** Dual Bed Fuel Conversion: Fundamentals and Technologies
12:30-14:00	**Lunch**														
14:00-15:00 15:00-16:00	**TuO-T216B** Multifunctional Smart Materials	**TuO-T219B** Photovoltaics	**MoPL-GLS-4** **TuO-GLSA3** GLS-11	**TuO-GLSB1** GLS-11	**TuO-T220** Process and Technology for Energy and Environment II – Yonsei ChE Global Network Forum	**TuO-T602B** New Education Paradigm for the 21st Century	**TuO-T222** Shape-Dependent Catalysis: Experiment and Simulation	**TuO-T604** Recruiting and Retention	**TuO-AP02** APCBM 2013	**TuO-T107** Chemical Engineering in Colloids Research	**TuO-T209** Gasifier (14:00~16:20)	**TuO-T205B** Current Issue for Automotive Emission Control Catalytic Technology	**TuO-T126** Reaction Engineering for Energy and the Environment	**TuO-T213B** Membranes for Sustainable Technologies	**TuO-T110B** Dual Bed Fuel Conversion: Fundamentals and Technologies
16:00-16:30	Coffee Break														
16:30-17:30		**TuO-T202** Bio-fuel	**TuO-GLSA4** **TuO-GLSE2** GLS-11	**TuO-GLSH1** **TuO-GLSH2** GLS-11	**TuO-T507** Separation Technology	**TuO-T602C** New Education Paradigm for the 21st Century	**TuO-T115** Materials Synthesis		**TuO-AP03** APCBM 2013	**TuO-T117** Microfluidics	**TuO-T224** Wastewater & Water Treatment	**TuO-T210** Hydrogen Production from Biomass	**TuO-T105** Catalysis (16:30-17:50)	**TuO-T309** Functional Membranes	**TuO-T110C** Dual Bed Fuel Conversion: Fundamentals and Technologies
17:30-19:00	**Poster Presentation**														

CODE ABBREVIATION

Mo O – T1 01

- Mo: Day
- O: Presentation Type
- T1: Topic
- 01: Session Title

DAILY PROGRAM

Aug. 21 (Wed)

Aug. 21 (Wed)	Grand Ballroom (1F)					Asem Hall (2F)		Auditorium (3F)			Hall E (3F)			
	101	102	103	104	105	203	208	Auditorium	Room 1	Room 2	E1	E2	E3	E4
08:15-08:25	**Morning Meditation Time** (Auditorium, 3F)													
08:30-09:20	**WePL-01. Advanced Fuels from Advanced Plants** **Jay D Keasling, USA** (Auditorium, 3F)													
09:20-10:10	**WePL-02. Bioeconomy Science - A Chemical Engineering Perspective** **Wolfgang Marquardt, Germany** (Auditorium, 3F)													
10:10-10:30	Coffee Break													
10:30-11:30 11:30-12:30	**WeO-T104** Catalysis (10:30-12:50)	**WeO-T306** Emerging Materials and Technologies in Polymer Electrolyte Membranes for Fuel Cell Application	**WeO-GLSB2** **WeO-GLSG1** GLS-11	**WeO-T218** Organic and Inorganic Materials for Energy and Environment I – Yonsei ChE Global Network Forum	**WeO-GLSF2** **WeO-GLSD2** GLS-11	**WeO-T304** Biotechnology for Future Chemical Industry	**WeO-T214A** Microalgae-based Biofuels and Bioproducts	**WeO-AP04** APCBM 2013	**WeO-T413** Sustainable Supply Chain Design and Operation	**WeO-T601** Chemical Engineering Curriculum Development	**WeO-T302** Bio-Inspired & Biomimetic Material	**WeO-T127** Reaction Engineering for Nanoparticles and Thin Films	**WeO-T125** Process: Fundamental	**WeO-T110A** Dual Bed Fuel Conversion: Fundamentals and Technologies
12:30-14:00	**Lunch**													
14:00-15:00 15:00-16:00	**WeO-T129A** Rheology	**WeO-T506** Promotion of University-industry Cooperation	**WeO-GLSG2** GLS-11 **GLS-11** Committee Meeting	**WeO-T220** Process and Technology for Energy and Environment I – Yonsei ChE Global Network Forum (14:00~16:20)	**WeO-GLSC1** **WeO-GLSC2** GLS-11	**WeO-T202A** Bio-fuel	**WeO-T214B** Microalgae-based Biofuels and Bioproducts	**WeO-AP05** APCBM 2013	**WeO-T502A** Chemical Reaction Technology	**WeO-T605** Teaching Pedagogy	**WeO-T303A** Biomedical Applications	**WeO-SS02** Global Forum on Sustainability (Invited Only)	**WeO-T111A** Fluid Mechanics	**WeO-T110B** Dual Bed Fuel Conversion: Fundamentals and Technologies
16:00-16:10	Break													
16:10-17:10 17:10-18:10	**WeO-T129B** Rheology					**WeO-T202B** Bio-fuel	**WeO-T202C** Bio-fuel	**WeO-AP06** APCBM 2013	**WeO-T502B** Chemical Reaction Technology	**WeO-T119** Modeling & Simulation (16:10~17:50)	**WeO-T303B** Biomedical Applications (16:10-17:50)		**WeO-T111B** Fluid Mechanics (16:10-17:30)	**WeO-T110C** Dual Bed Fuel Conversion: Fundamentals and Technologies (16:10-17:40)
18:30-20:30	**Gala Dinner**													

CODE ABBREVIATION

Mo O – T1 01

- **Mo** — Day
- **O** — Presentation Type
- **T1** — Topic
- **01** — Session Title

DAILY PROGRAM

Aug. 22 (Thu)

Aug. 22 (Thu)	Grand Ballroom (1F)					Asem Hall (2F)		Auditorium (3F)			Hall E (3F)			
	101	102	103	104	105	203	208	Auditorium	Room 1	Room 2	E1	E2	E3	E4
08:15-08:25	**Morning Meditation Time** (Auditorium, 3F)													
08:30-09:20	**ThPL-01. Chemical Engineering in the Age of New Challenge** **Dong-Soo Hur, Korea** (Auditorium, 3F)													
09:20-10:10	**ThPL-02. China's Petrochemical Industry: Seeking Opportunities Amidst Challenges** **Tianpu Wang, China** (Auditorium, 3F)													
10:10-10:30	**Coffee Break**													
10:30-11:30 11:30-12:30	**ThO-T123** Phase Equlibrium (10:30-12:50)	**ThO-T104A** Catalysis	**ThO-SS01** Recent Progress & Practice of Korean Petrochemical Industry	**ThO-T104B** Catalysis	**ThO-T401** Applications to Energy Systems	**ThO-T412A** Sustainable Process-Product Design I	**ThO-T415** Technology and Culture for Process Safety	**ThO-AP07** APCBM 2013	**ThO-T409** Process Design and Intersification	**ThO-T202** Bio-fuel	**ThO-T224A** Wastewater & Water Treatment	**ThO-T312** Nanostructured Materials for Chemical Engineering Processes - Celebrating the 50th Anniversary of Department of Chemical & Biological Engineering, Korea University	**ThO-T305A** Carbon-based Materials	**ThO-T313** Next-Generation Polymer Based Solar Cells
12:30-14:00	**Lunch**													
14:00-15:00 15:00-16:00	**ThO-T109A** Computational Fluid Dynamics	**ThO-T104C** Catalysis	**ThO-T116A** Membrane Separation (14:00-16:20)	**ThO-T404** Energy System Optimization and Control	**ThO-T414** Systems Informatics for Virtual Sensing and Process Monitoring	**ThO-T412B** Sustainable Process-Product Design II	**ThO-T402** Control and Optimization of Chemical Batch Processes	**ThO-AP08** APCBM 2013	**ThO-T408** Process Control	**ThO-T101A** Adsorption	**ThO-T224B** Wastewater & Water Treatment	**ThO-T308A** Energy Conversion and Storage	**ThO-T305B** Carbon-based Materials	**ThO-T311** Nanomaterials & Nanotechnology
16:00-16:30	**Coffee Break**													
16:30-17:30	**ThO-T109B** Computational Fluid Dynamics	**ThO-T104D** Catalysis	**ThO-T116B** Membrane Separation (16:30-17:50)	**ThO-T403** Economics and Sustainability (16:30~17:50)	**ThO-T114** Heat and Mass Transport (16:30-17:50)	**ThO-T203** Biorefinery	**ThO-T407** Practice of Safety in Industry	**ThO-AP09** APCBM 2013	**ThO-T132** Thermophysics (16:30-17:50)	**ThO-T101B** Adsorption	**ThO-T224C** Wastewater & Water Treatment	**ThO-T308B** Energy Conversion and Storage (16:30-17:50)	**ThO-T305C** Carbon-based Materials (16:30-17:50)	**ThO-T207** Fuel Cell: Catalytic Hydrogen Production (16:30-17:50)
17:30-19:00	**Poster Presentation**													

CODE ABBREVIATION

Mo O – T1 01

- Mo: Day
- O: Presentation Type
- T1: Topic
- 01: Session Title

DAILY PROGRAM

Aug. 23 (Fri)

Aug. 23 (Fri)	Grand Ballroom (1F)					Asem Hall (2F)		Auditorium (3F)			Hall E (3F)			
	101	102	103	104	105	203	208	Auditorium	Room 1	Room 2	E1	E2	E3	E4
08:15-08:25	**Morning Meditation Time** (Auditorium, 3F)													
08:30-09:20	**FrPL-01. The Pivotal Role of Chemical Engineering Innovations in the Successful and Sustainable Development of Alberta's Oil Sands and Bio-resources** **Duke du Plessis, Canada** (Auditorium, 3F)													
09:20-10:10	**FrPL-02. Systems Engineering at the Nanoscale: Towards Molecular Factories, Synthetic Cells, and Adaptive Devices** **George Stephanopoulos, USA** (Auditorium, 3F)													
10:10-10:30	**Coffee Break** (Grand Ballroom Lobby, 1F)													
10:30-11:30	**FrO-T411** Process Optimization	**FrO-T405** Micro-nano System Modeling and Simulations		**FrO-T118** Microreactor	**FrO-T410** Process Modeling	**FrO-T311** Nanomaterials & Nanotechnology	**FrO-T310** Functional Thin Films		**FrO-T203** Biorefinery	**FrO-T221** Sequestration of Carbon Dioxide	**FrO-T113** Gas Hydrates	**FrO-T104** Catalysis	**FrO-T128** Recent Research Trend in Petroleum Displacement Technologies	**FrO-T208** Fuel Cell: System
11:30-12:30														

CODE ABBREVIATION

Mo O – T1 01

Day · Presentation Type · Topic · Session Title

Probing the Yield Behaviour of Suspensions under Combined Shear and Compression

Hui-En Teo, Anthony Stickland, Robin Batterham, Peter Scales

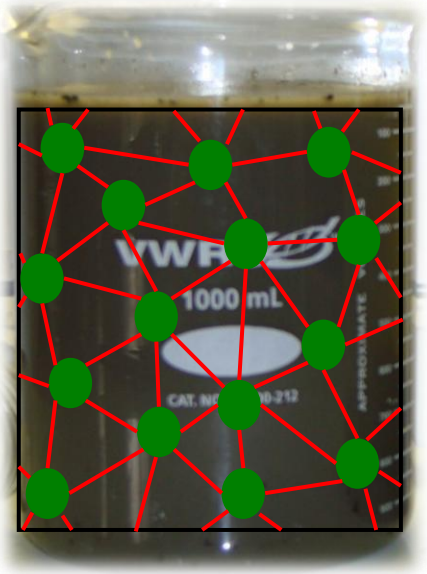
9th World Congress of Chemical Engineering
Coex, Seoul, Korea
18 to 23 August, 2013

Acknowledgements

- ASR Howard See Young Rheologist Travel Award 2012
- BCIA Postgraduate Research Scholarship
- PFPC, Australian Research Council
- Department of Chemical and Biomolecular Engineering, the University of Melbourne

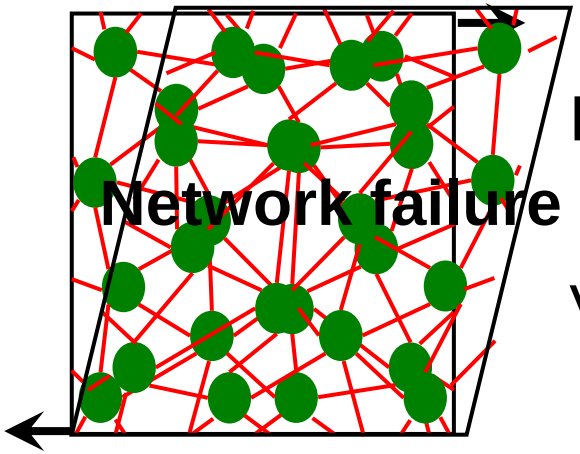
Why do we study suspensions?

Particulate Suspensions



Particulate Suspensions

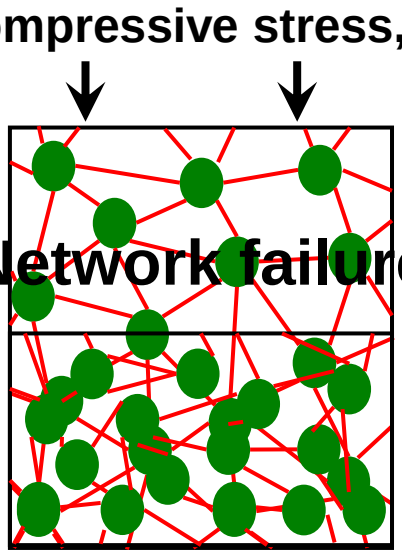
…in 1-D shear



Elastic solid ($\sigma < \sigma_y$)

Viscous fluid ($\sigma > \sigma_y$)

…in 1-D compression



Incompressible ($p_{load} < p_y$)

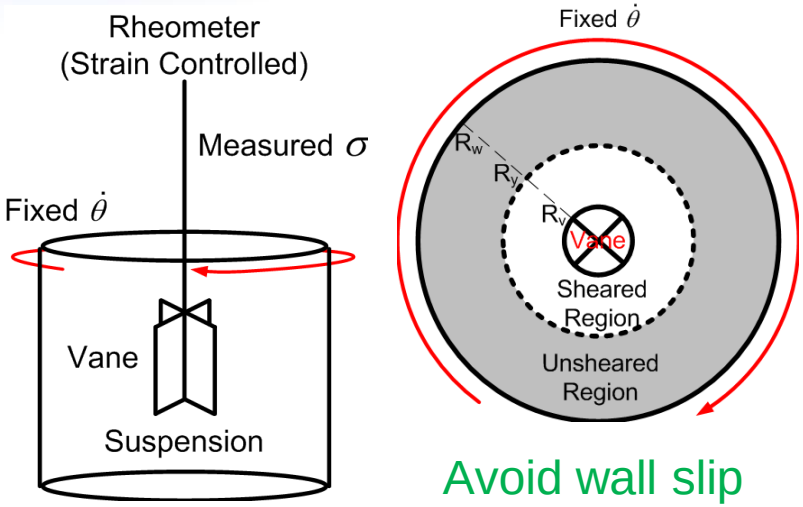
Compressible ($p_{load} > p_y$)

Fluid

Buscall and White, The consolidation of concentrated suspensions: 1. The theory of sedimentation, *J. Chem. Soc., Faraday Trans. 1*, 1987, 83, 873-891

Characterisation of Particulate Suspensions

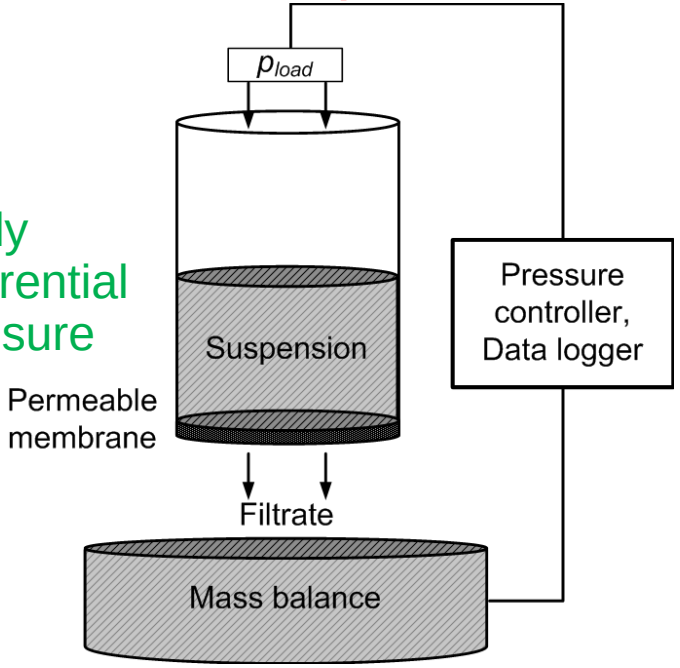
…in 1-D shear



Avoid wall slip

…in 1-D compression

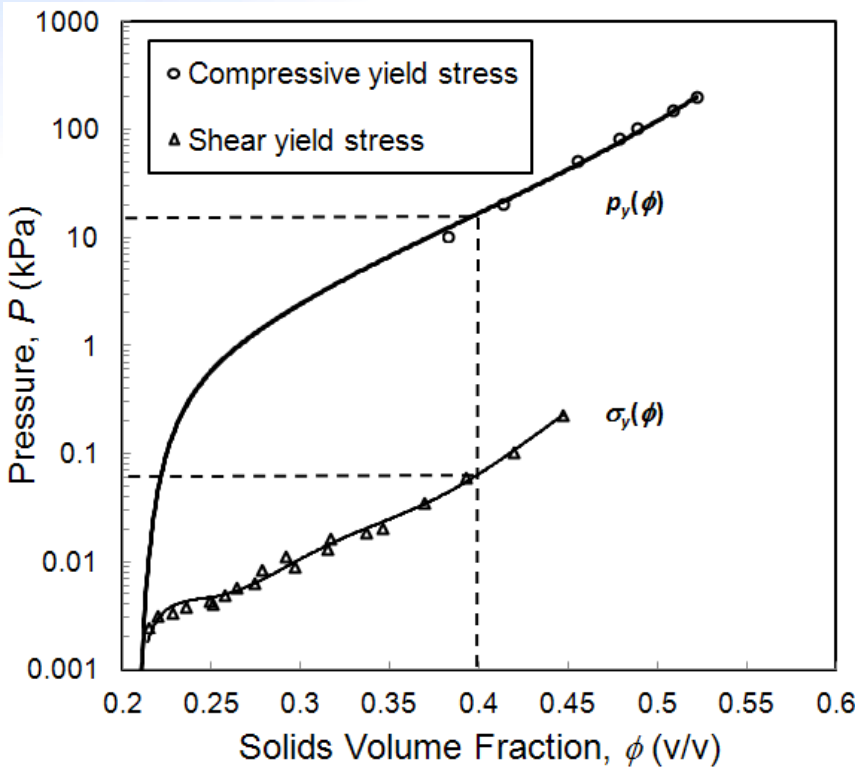
Apply differential pressure



Fisher et al, The bucket rheometer for shear stress-shear rate measurement of industrial suspensions, *J. Rheol.*, 2007, 51(5), 821-831

de Kretser et al, Rapid filtration measurement of dewatering design and optimization parameters, *American Inst. of Chem. Eng.,* 2001, *47* (8), 1758-1769

Comparison of σ_y and p_y



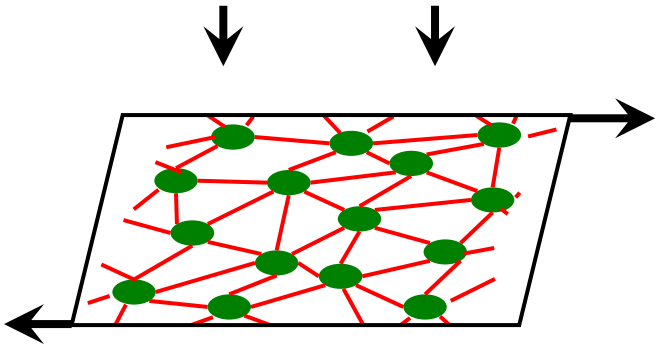
Effect of σ on p (and vice versa) can be ignored in largely 1-D processes:

- **Shear:** pipe flow of non-settling suspensions
- **Compression:** pressure leaf filtration

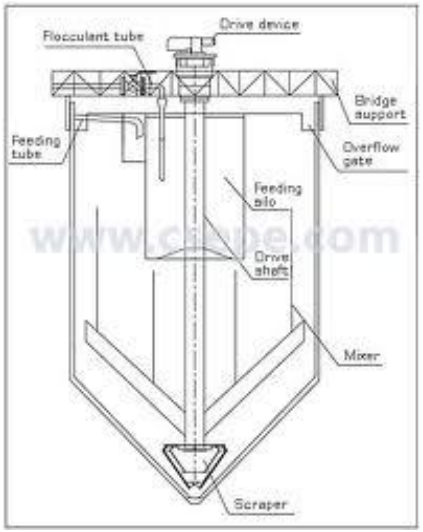
Combination of σ and p

…encountered in many industrial processes!

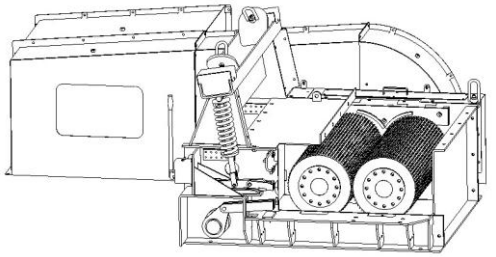
Compressive stress, p_{load}



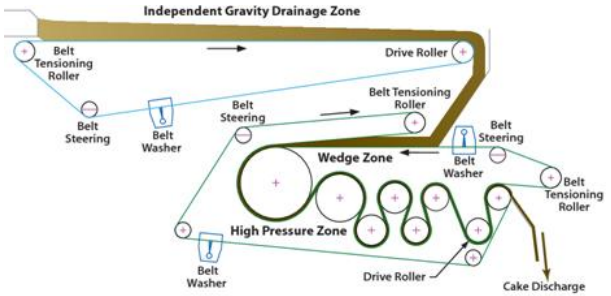
Shear stress, σ



Raked thickening



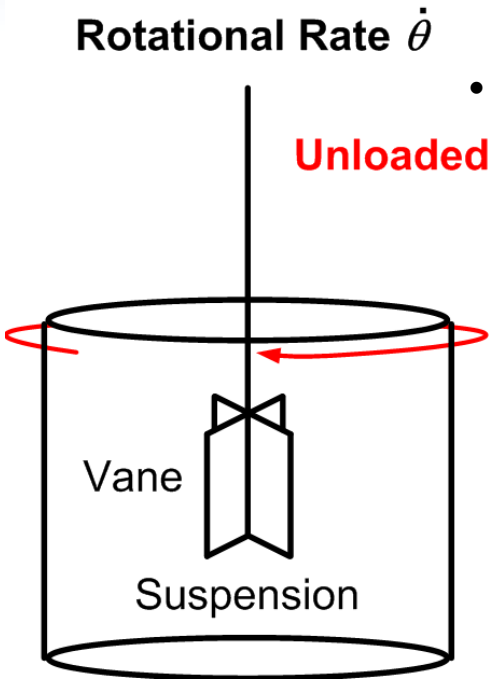
Roll compression

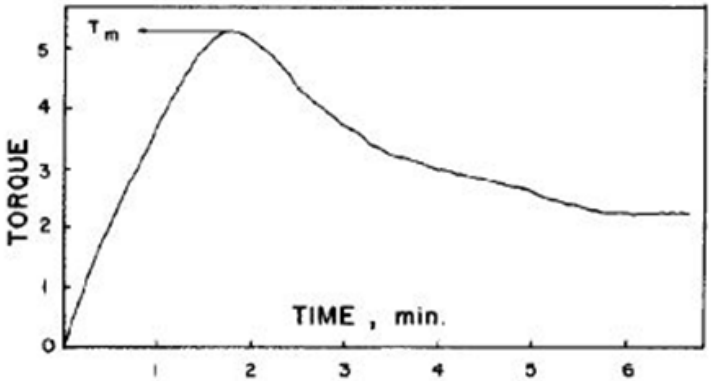


Belt filtration

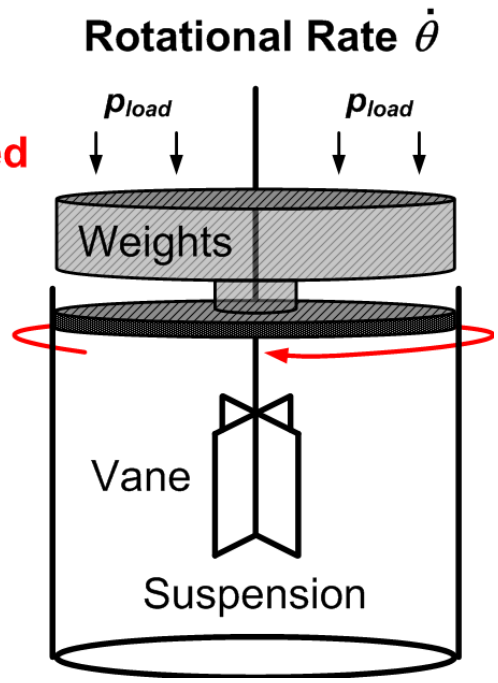
What we have done…

- Calcium carbonate in 0.01M KNO3, particle$_d$ = 5.8 μm, ϕ = 0.40
- p_{load} = 2.38 kPa (15.9% of p_y)
  1.15 kPa (7.7% of p_y)
- 1. Stress relaxation
  2. Constant strain rates

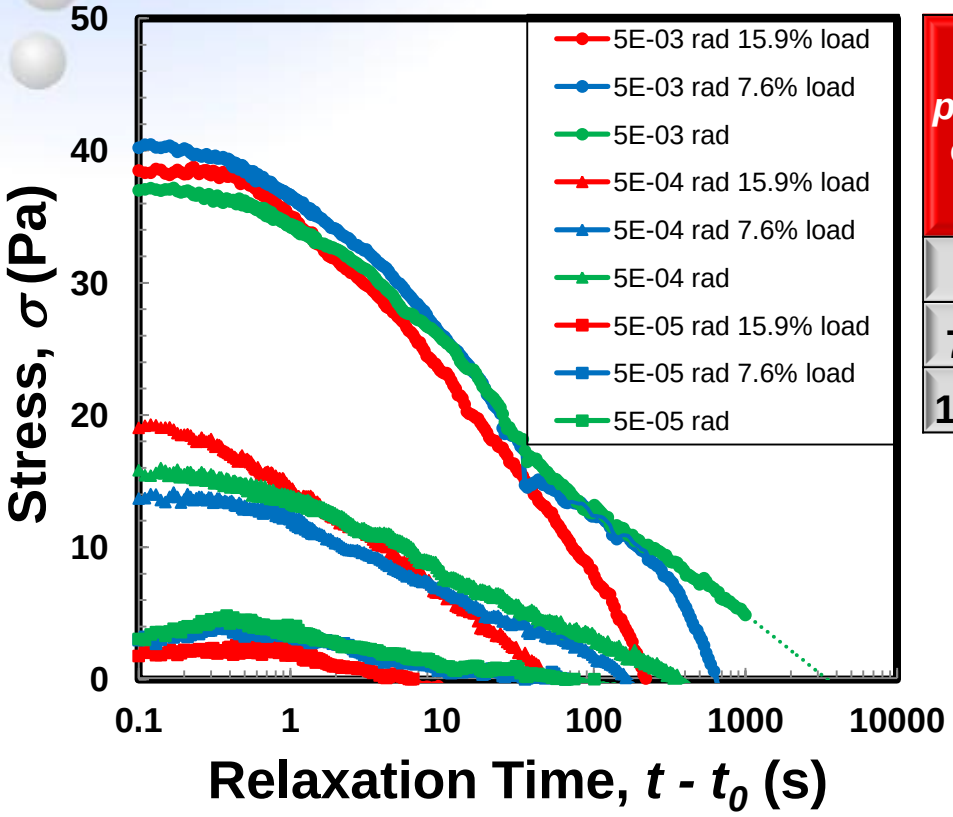




Nguyen and Boger, Direct yield stress measurement with the vane method. *J. Rheol.*, 1985, 29(3), 335-347



Results – Stress Relaxation

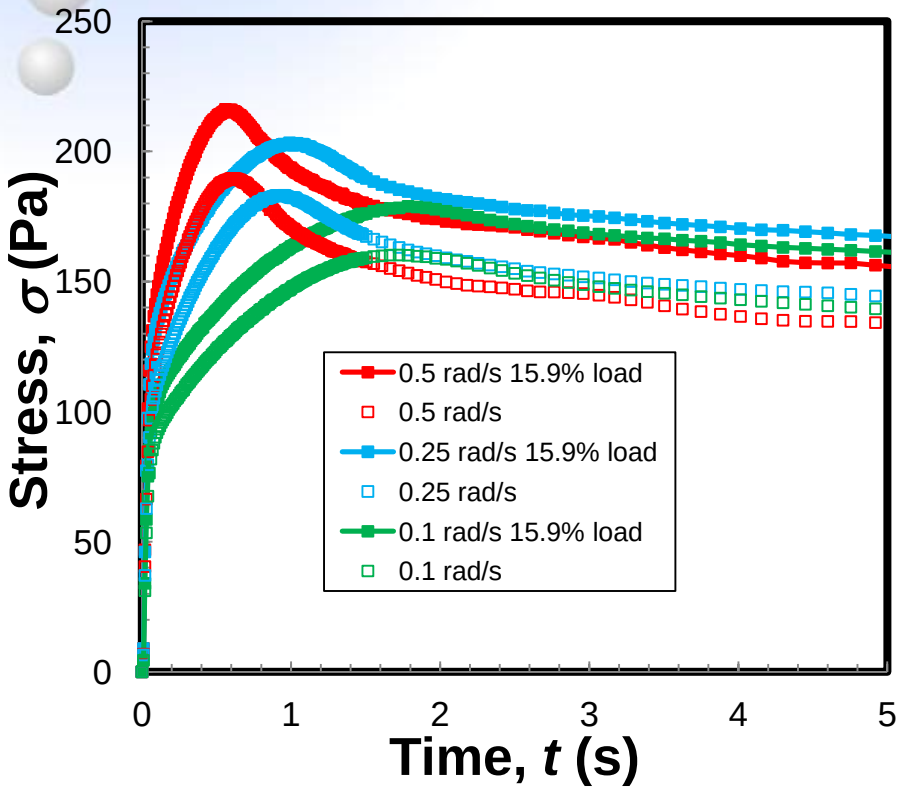


When $\phi = 0.40$, $p_y = 15$ kPa:

p_{load} % of p_y	Displacement					
	5 X 10^{-5} rad		5 X 10^{-4} rad		5 X 10^{-3} rad	
	σ_{peak} (Pa)	t_{rel} (s)	σ_{peak} (Pa)	t_{rel} (s)	σ_{peak} (Pa)	t_{rel} (s)
0%	4.8	58.7	15.9	367.3	37.4	3000*
7.7%	4.2	41.8	14.2	168.2	40.6	643.1
15.9%	2.7	6.7	19.8	49.5	40.1	228.3

- Negative correlation between p_{load} % and t_{rel}
- p_{load} % contributes to higher σ_{peak} only at higher displacements

Results – Constant Rates



p_{load} % of p_y	Rotational Rate		
	0.5 rad/s	0.25 rad/s	0.1 rad/s
	σ_{peak} (Pa)	σ_{peak} (Pa)	σ_{peak} (Pa)
0%	189.7	183.1	160.2
15.9%	216.2	203.3	178.9

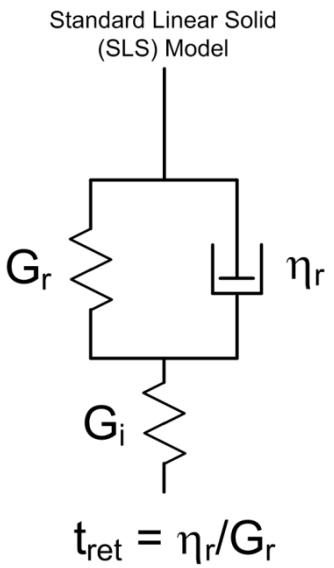
- Positive correlation between p_{load} % and σ_{peak} at all rotational rates measured

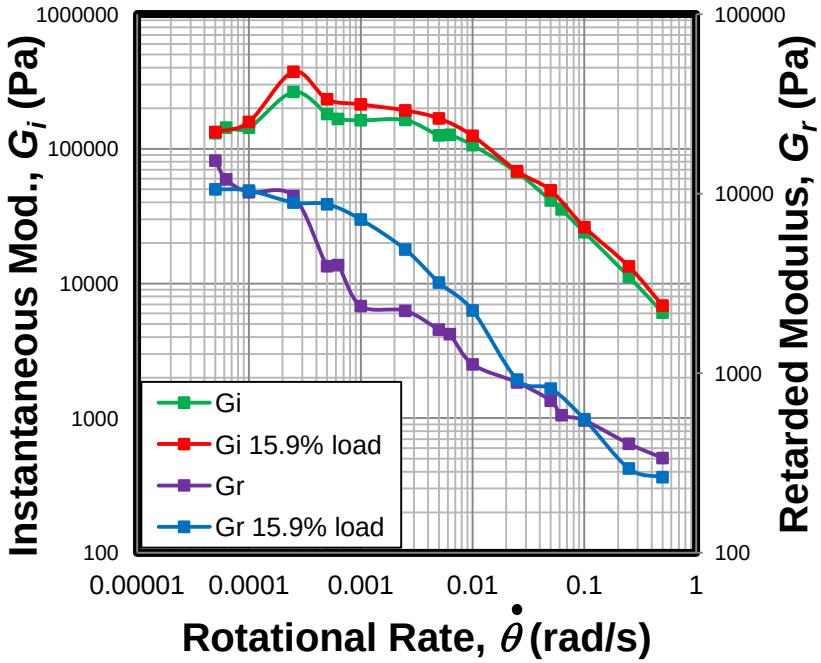
Results – Constant Rates (SLS)

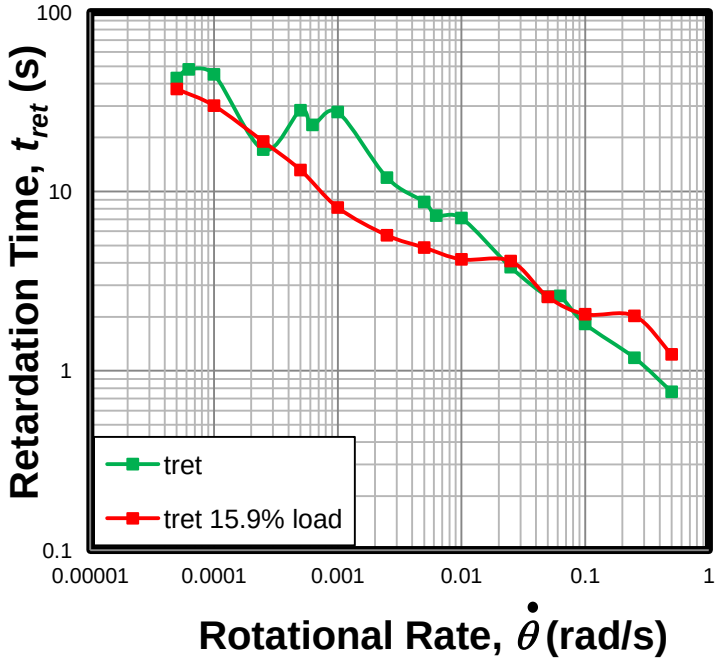
Constant Rate Solution:

$$\sigma(t) = \dot{\gamma}_0 \frac{G_i G_r}{(G_i + G_r)^2}\left[(G_i + G_r)t + t_{ret} G_i\left[1 - \exp\left[-\left(1 + \frac{G_i}{G_r}\right)\frac{t}{t_{ret}}\right]\right]\right], \quad t < t_0$$

$$\dot{\gamma}_0 = \frac{2\dot{\theta}_0}{(1 - \frac{R_v^{\,2}}{R_y^{\,2}})}$$







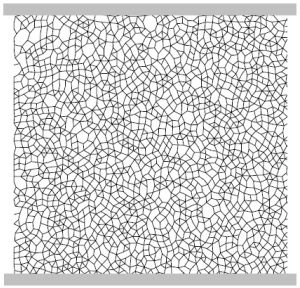
What could be happening?

Phenomena Observed

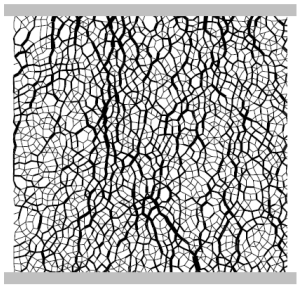
- In stress relaxation, stress dissipates quicker when a load is placed on the material
- In constant rate tests, stress peaks are higher when a load is placed on the material

Possible Explanations

Force Chains



Unloaded Network



Loaded Network

Sun et al, Understanding force chains in dense granular materials, *int. J. of Modern Physics B*, 2010, 24(29), 5743-5759

In conclusion…

- Most rheological work through to application has concentrated on pure shear or compression, with very little done on multi-D combinations of both forces.
- Controlled strain rate and stress relaxation experiments can be modified to understand 2-D combined shear and compression
- Based on my results, stress responses indicate that higher maximum stresses and shorter relaxation times can be achieved when a suspension is loaded.
- Influence of force chains to be explored

Thank you (kamsahamnida) for listening!☺