Howard See Young Rheologist Travel Award

Report to the Australian Society of Rheology

Recipient: David I. Verrelli

Conference: 6th Korean–Australian Rheology Conference (KARC)

Location: Daejeon, Korea

Date: September 2011

Scope

This report primarily covers my attendance at the **6th Korean–Australian Rheology Conference ("KARC") 2011** conference in Daejeon, Republic of Korea. This was made possible by the receipt of funds from the inaugural Howard See Young Rheologist Travel Award (2010), awarded by the Australian Society of Rheology (ASR). A side-trip to **KIGAM** was also made, with a small amount of additional support from CSIRO.

Overview

The trip was made in order to attend the 6th Korean–Australian Rheology Conference ("KARC") 2011[i], at which I presented a conference paper, which appeared to be well received, and generated some interest. At the conference I was also able to listen to presentations on new scientific findings. As regards 'networking', it was as much a case of cementing existing relationships as building new ones.

At KIGAM the main activity was to deliver a seminar. This was received with a pleasing amount of interest. I also had meetings with a few staff.

Timeline

Friday	2011-09-23	Depart Melbourne.
Saturday	2011-09-24	Arrive in Daejeon.
Sunday	2011-09-25	Welcome reception for KARC 2011.
Monday–Tuesday	2011-09-26 – 2011-09-27	KARC 2011.
Wednesday	2011-09-28	Meetings at KIGAM.
Thursday	2011-09-29	Depart Daejeon
Friday	2011-09-30	Arrive in Melbourne.

[i] http://plaza4.snu.ac.kr/~karc2011/index.php

KARC 2011

Background

The Korean–Australian Rheology Conferences are jointly organised by the Korean Society of Rheology ("KSR", 한국유변학회)[i] and the Australian Society of Rheology ("ASR")[ii]. The collaboration between the societies was originally championed by two senior rheologists from the two respective societies, Prof. Jae Chun HYUN and Prof. David BOGER[iii], and complements the co-published journal, *Korea–Australia Rheology Journal* ("KARJ"), that was first issued in 1989.

KARC was first run ten years ago, in 2001, and is held biennially, alternating between venues in Korea and Australia. The majority of the participants are generally from Korea and Australia.

This year the KSR hosted the conference, and invited also the Korean Society of Plastics Engineers ("SPE Korea")[iv]. SPE Korea ran two sessions in parallel with the 'main' conference. The stated ideal was to encourage intermingling of the rheology societies with SPE Korea, although it is not clear how much of this occurred.

The great majority of delegates were from Korea. This is partly due to the greater size of the KSR compared to the ASR[v], not to mention the involvement of SPE Korea. But the other reason is that that it was held in Korea, allowing a large number of Korean postgraduate (Masters and Ph.D.) students to attend — the majority of whom (I guess) presented posters.

There were around 10 Australian delegates, almost all based in Melbourne: 3–4 from RMIT, 2 each from Monash and UniMelb, 1 from CSIRO (me!), and 1 from USyd.

A similar number of delegates attended from China, prominent among them Prof. Ying-She LUO (Central South University of Forestry and Technology) and colleagues.

There were a few delegates from Japan (Prof. Hiroshi WATANABE, Kyoto; A/Prof. Yang-Ho NA, Hokkaido); the U.S.A. (Siyoung Q. CHOI, UCSB); and Canada (Ramesh SUBRAMANIAN, Laurentian).

Technical flavours

The presentations were across seven themes.

1A.	General rheology
1B.	Polymer processing
2A. & 3A.	Polymer melts and solutions
2B. & 3B.	Suspension and Colloids
4A.	Micro/Nano rheology
4B.	Computational rheology
SPE Korea 1 & 2.	Rheology for Industrial Applications
Poster Session	

More details in the *Appendix* and online at http://plaza4.snu.ac.kr/~karc2011/program.php.

---

[i] http://www.rheology.or.kr/

[ii] http://www.rheology.org.au/

[iii] *Cf.* http://www.pfpc.unimelb.edu.au/news/pubs/pdf/annualreport01.pdf

[iv] http://www.4spe.org/location/asia/korea

[v] A couple of hundred active members, versus a few dozen active members. For comparison, the Chinese rheology society has about 1000 members [according to Prof. LUO].

As highlighted in Prof. SCALES's presentation, rheology has traditionally put most effort into researching polymer melts and solutions, and this is reflected above.

There were two plenary presentations (1 Australian, 1 Korean), and six keynotes lectures (2 Australians, 2 Koreans, 1 Chinese and 1 Japanese).

Technical highlights

Prof. Jae R. YOUN (Seoul National U.): plenary presentation showcasing his group's work on injection-moulding. A key issue is residual stress, which causes slow deformation (warpage, shrinkage) in the field. Applications range from very large pieces for car dashboards (over 1 metre, with multiple gates, and a decorative 'film' on one side) to very small electrical connectors (tolerance down to 20 micron). Technologies employed include specialist software (*Moldflow*, FEM, *etc.*) and a 3D laser scanner.

Prof. J. Ravi Prakash (Monash): keynote reviewing the state of knowledge in modelling semi-dilute polymer solutions.

Dr. Anthony D. STICKLAND (UniMelb): presented very preliminary results on measuring shear yield stresses under the action of a compressive stress. His concept of the stresses at work differ somewhat from my concept, but it was good to see another researcher exploring a topic related to my presentation. Questions afterward revealed a lack of familiarity among some in the audience with the vane technique, which was surprising to me, but probably reinforces the observation that many 'rheologists' specialise in viscoelastic deformation, and do not deal with shear yield stresses.

Prof. Florian J. STADLER (Chonbuk): presented a correlation allowing a surrogate parameter that can be measured quickly (~20 minutes) to stand in as an approximate analogue of the linear steady-state elastic compliance, J_e^0, which takes a few days to reliably estimate. Additionally, he mentioned that at short relaxation times (or high frequency oscillation) linear polymer chains dominate, while at long relaxation times (or low frequency oscillation) branched polymer chains dominate.

Dr. Rahul K. GUPTA (RMIT): presented another application of the alternative Reynolds number formulation developed by Prof. Paul SLATTER (RMIT) and collaborators at CPUT for application to pipe flow of yield-stress materials. Dr. R. PRABHAKAR (Monash) made a useful suggestion for improving the formulation by considering only the portion of the material in the annulus where a velocity gradient exists (*i.e.* where the shear stress exceeds the yield stress).

Dr. Fuzhong QI (USyd): presented an interesting analysis of random close packing of bimodal hard-sphere suspensions. In subsequent discussion with him, I was interested to realise that it is not just the lower limit of solidosity that is 'fuzzy' (due to arching, *etc.*), but that the upper limit is also ill-defined (due to structuring, *i.e.* deviation from randomness).

Prof. Peter J. SCALES (UniMelb): plenary presentation which again tried to approach the problem of combined shear and compressive forces/yielding. With his co-workers he proposes a "hyperelasticity" model. An interesting video demonstrated one of the issues with yield-stress materials, with a flocculated suspension undergoing a mixture of plug flow and viscous (laminar) flow, so that dye injected into the system did not disperse into the plug-flow region.

Prof. In Seok KANG (Pohang): presented an interesting paper comparing the known phenomenon of electrowetting on dielectrics ("EWOD") with a newer topic of electric charging on droplets ("ECOD").

Dr. Wook Ryol HWANG (Gyeongsang): described modelling of particles being captured by a depth filtration medium. Interestingly, the effect of a particle on the flow field can be obtained by difference, showing that the particle's presence superimposes a hyperbolic flow pattern on the surrounding flow.

Dr. Sung Up CHOI (Seoul National U.): presented modelling results showing that the vortexing regions next to the entrance to a sudden pipe contraction are void of particles if the particles are mutually attractive.

My presentation

My presentation underwent some last minute changes in Korea, and in the end turned out fairly well. There was a decent audience in the room, at around 40 people. I began by thanking the ASR for the funds made available for my travel in the form of the Howard See Young Rheologist Travel Award, and acknowledged support from elsewhere, in particular the rheometrical results from J. FOONG which I had reanalysed. I then spent a moment honouring Howard SEE's life. After this I went into the technical matter, '*Influences of Normal Stress Differences on Measurements of Yield Stress*', and managed to get through this in about 15 minutes, leaving 5 or so minutes for questions, of which there was only one.

The question came from Prof. Peter SCALES (UniMelb), who was effectively asking whether the "yield stress" that we typically measure is a 'true' yield stress, and if not what the consequences would be for my analysis. Although this is quite an old question, here it was prompted by more recent rheometrical measurements in his group which raised uncertainties about some elements of the data measured by FOONG, specifically on the question of critical yield strain[i]. The question was more in the vein of requesting my opinion on a matter I might wish to consider, rather than a statement of right or wrong. As agreed in discussions afterward, the intention of my presentation was to raise peoples' awareness of my technical topic, and did not necessarily set out to 'prove' something.

As Dr. Andrew CHRYSS put it previously, my proposition was somewhat 'controversial' in terms of presenting a new idea[ii]. Hence I was pleased to hear one audience member asking another[iii] as they walked out, "Did you have any comments about the last presentation?"

Subsequently, over the lunch break, Prof. Hyoung Jin CHOI (Inha) mentioned that he was interested in the topic, as he had previously looked at the first normal stress difference (manifest as rod-climbing) for particle-filled 'Boger fluids'. This phenomenon is due to the fluid rather than the particles, and so was not quite the same as what I had been describing.

Prof. See Jo KIM (Andong) had a longer discussion with me, albeit quite general. He talked about his interest in the physics of these kinds of problems.

Networking & discussions

The bulk of the outside discussions I spent with other delegates from Melbourne, all of whom I knew through the ASR. I met Dr. Fuzhong QI (USyd), who works with the well-known Prof. Roger TANNER.

Of the Koreans, Prof. Hyoung Jin CHOI (Inha) was especially friendly and hospitable. He also hosted the delegates from RMIT at his university the following day.

I also had a nice discussion with Prof. Jae R. YOUN (Seoul National U.) about his work, which involves modelling and experimentation on injection moulding, primarily for the automotive sector. He mentioned that nowadays there is more competition to obtain funding than

---

[i] Prof. SCALES suggested that more recent data showed the alumina suspensions were only truly elastic up until about 3 % of the critical shear strain. Together we were unable to come up with a clear idea of how the material would then behave between 3 and 100 % of the critical strain; it was suggested that it would "creep", corresponding to viscous/viscoelastic deformation. Upon reflection, this would make the estimated critical shear strain a 'nominal' value that grossly overestimates the 'true' value.
On the other hand, Prof. SCALES also noted that thermoresponsive gels [which 'solidify' into a uniform network] appear to exhibit 'true' elasticity all the way up to the critical strain.

[ii] Strictly speaking, the application of old concepts in new ways.

[iii] Prof. Florian STADLER (Chonbuk).

historically had been the case, and each of the competing research institutions is forced to raise their standard if they are to remain competitive.

I spoke with Prof. Ying-She LUO (Central South U. of Forestry and Technology). I was interested to know that even in China the funding situation is highly competitive.

I had brief conversations with a number of other delegates.

Exhibition

There was a minimal exhibition, comprising perhaps one or two exhibitors.

Notable quotes

"When I go back to Japan I will tell everyone 'come to this conference'. I want to try to persuade our Society to join next time." — Japanese delegate. He praised the high standard of the talks.

Cultural tour

The conference rounded out with a cultural tour, and for me presented another opportunity to continue discussions, as much as taking in the cultural aspects. (I had spent 2½ weeks in Korea in February 2011, and travelled around.)

Visit to KIGAM

KIGAM is the *Korea Institute for Geoscience and Mineral Resources*. KIGAM has an annual budget of about 109 million USD. Their staff count is 422 (348 technical, and 74 administrative).

CSIRO Process Science and Engineering, where I work, mostly deal with 3 Departments within the *Mineral Resources Research Division*. According to the 2010 Annual Report[i]: "The Mineral Processing and Metal Recovery Departments deal with the beneficiation of mineral resources for value added materials, utilization of coal, metallurgy, and recycling of urban wastes. The Industrial Materials Research Department focuses on synthesis, fabrication and application of nanosized materials from mineral resources, and ultra high purity rare metals."

The 'main event' of the visit was my seminar. We also held general discussions, and I inspected some new laboratory facilities.

Seminar

The seminar, '*Variations in the induction period for particle–bubble attachment — PREVIEW*', was a 'preview' of what I will deliver at the *Flotation '11* conference in Cape Town this November 2011. The presentation was generally well received. There were two main issues that arose. One was the need to be very careful in defining what "mobile" and "immobile" bubble surfaces mean. The other was to ensure that the original motivation for doing the work (*i.e.* application oriented) is communicated.

[i] http://www.kigam.re.kr/Contents/mboard.asp?strBoardID=B028 The 2010 edition is a very large file (157 MB).

Meetings

I met again Dr. KIM (김동진), Dr. LEE (이수정), Dr. PARK (박경호) and (very briefly) Dr. CHO (조성욱). On this trip I also met one new member of staff, Dr. Chandra Sekhar Gahan, a couple of students[i], and some visiting researchers from India (typically on exchange for ~1 year).

Dr. Chandra Sekhar Gahan[ii], known as "Sekhar", joined about 6 months ago, after completing a postdoc at the University of Cape Town ("UCT"). His Ph.D. was completed at Luleå University of Technology (Sweden). Sekhar is a dynamic personality. His original training was in microbiology, and he subsequently moved into applying this to mineral processing.

Of the visiting Indian researchers, one was working on: spent catalysts, pyrrhite in coal, and technology to make economical the production of uranium from Korean deposits. Korean uranium deposits are low grade, but apparently the extraction technology is already developed; it is the 'back extraction' process that remains to be resolved.

Facilities

I inspected the new bioprocessing facilities in the laboratory that is immediately across the corridor from Dr. KIM. This is being set up by Dr. Chandra Sekhar Gahan, and comprised really high-quality bioreactor equipment (about 8 stirred tanks, each 2 L, but 1 L working volume). He had also just purchased a new mass spectrometer (?) or similar instrument.

Other elements of trip

Flight

The departure times were especially selected to ensure convenience of arrival into Incheon (touch-down at 14:05; plenty of time to catch bus to Daejeon, arriving in time for dinner) and departure from Daejeon (flight departing Incheon at 15:15, so catching bus at 'comfortable' time of about 09:00–09:30).

Bus

The 'limousine' airport bus seems to be the accepted way of getting between Daejeon and Incheon airport[iii]. Although it was advertised as taking over 3 hours to make the trip, my journey took about 2 hours 20 minutes, and another delegate had a similar journey time.

It is not necessarily obvious which stop is which in Daejeon. I thought that there were only three, except that my driver seemed to make one more stop. When arriving it is best to alight at the Government Complex, for ease of catching a taxi from the rank. When departing, the Doryongdong stop may be better, as this is only served by Gimpo and Incheon bus routes, so that confusion may be reduced. (On the other hand, there will be fewer people around to ask for assistance, should it be required.) See *Appendix* for more details.

Maps

Various maps are available. See *Appendix*.

---

[i] One from India, the other a local student (Seoyun CHOI).

[ii] http://www.linkedin.com/pub/chandra-sekhar-gahan/13/936/187 http://materialiaindica.ning.com/profile/chandrasekhargahan

[iii] It is also possible to travel by train, but this is somewhat more expensive and means changing in Seoul.

A p p e n d i x

The following are attached.

Maps and map extracts

Daejeon

Yuseong

Science precinct & Hotel area (annotated)

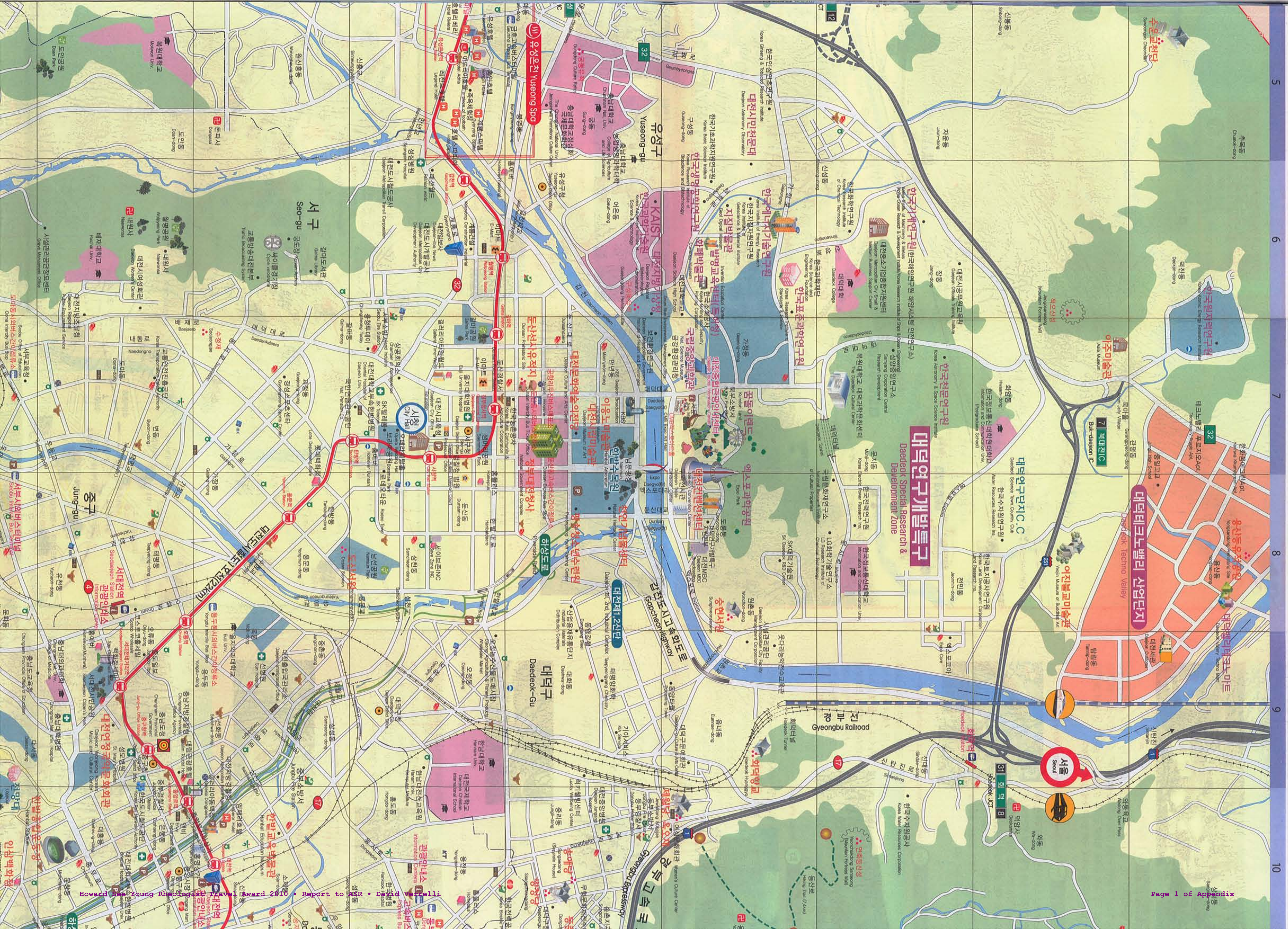
Instructions to 'Old Lotte Hotel' bus terminal for airport bus (in Korean)

Airport Bus maps

KARC

KARC programme

KARC presentation by D. I. Verrelli


대덕연구개발특구
Daedeok Special Research & Development Zone
유성온천 Yuseong Spa
유성구
Yuseong-gu
서구
Seo-gu
중구
Jung-gu
대덕구
Daedeok-Gu
경부선
Gyeongbu Railroad
대덕테크노밸리 산업단지
Daedeok Techno Valley
City Hall

범례 Legend

관광안내소 Tourist Infomation Center
대학교 Univ.
학교 School
박물관 Museum
산, 자봉우리 Mountain, Peak
백화점 Dept. Store
버스터미널 Bus Terminal
병원 Hospital
한식당 Korean Restaurant
양식당 Western Restaurant
우체국 Post Office
경찰서 Police Station
은행 Bank
호텔 Hotel
골프 Golf
문의 Inquiries
고속국도 Expressway

Page 2 of Appendix

Howard See Young Rheology's Travel Award 2010 • Report by ASR • David Verrelli

한국지질자원연구원
92 Gwahang-no

511 Daedeokdaero

(Doryong-dong 3-1)

(Doryong-dong 4-19)

13 Oncheon Munhwa-gil
(545-5 Bongmyung-dong)

http://www.wikimapia.org/#lat=36.3807476&lon=127.3606396&z=16&l=0&m=b

TAXI : 8:50

Doryong dong
Airport Bus T.

도룡동 공항버스

터미널

(구. Lotte Hotel)

David

9:31

대전광역시 유성구 봉명동 444-5 TEL.042) 823-2111
www.hotelriviera.co.kr

■ How to take a Limo for Daejeon

You can access to the Incheon Int'l Airport by the international flight all most of the world.
Please refer to the timetable at http://www.airport.kr/eng

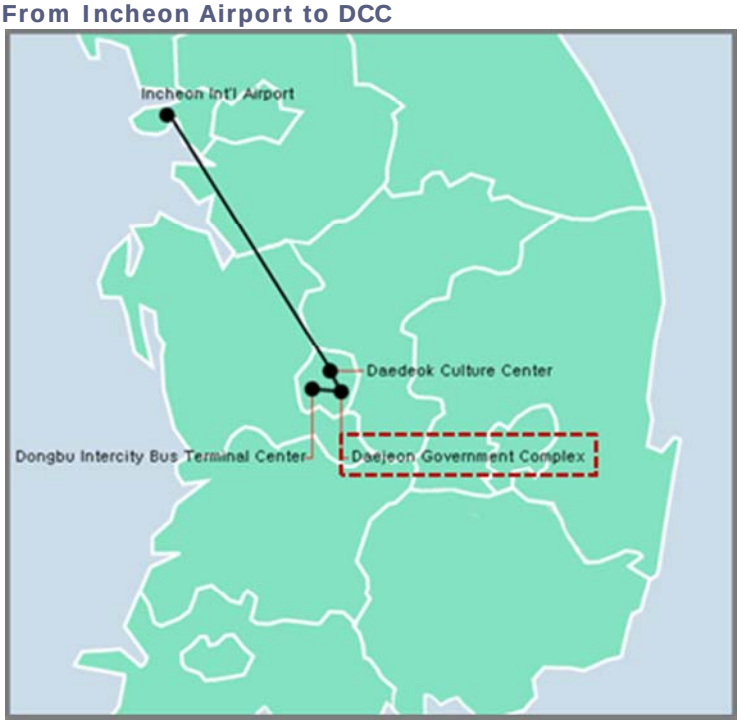
Step 1 : From the departures level (1st Floor) at Incheon Airport, find Gate 9.
Step 2 : At Gate number 9 (outside) there should be a little booth that sells bus tickets to Daejeon.
Step 3 : Please get off at the Daejeon Central Government Complex Stop.

Information is available at the transportation information counter concerning the timetable of limousine bus between the Incheon Int'l Airport and Daejeon, as well as the purchase of the bus ticket.

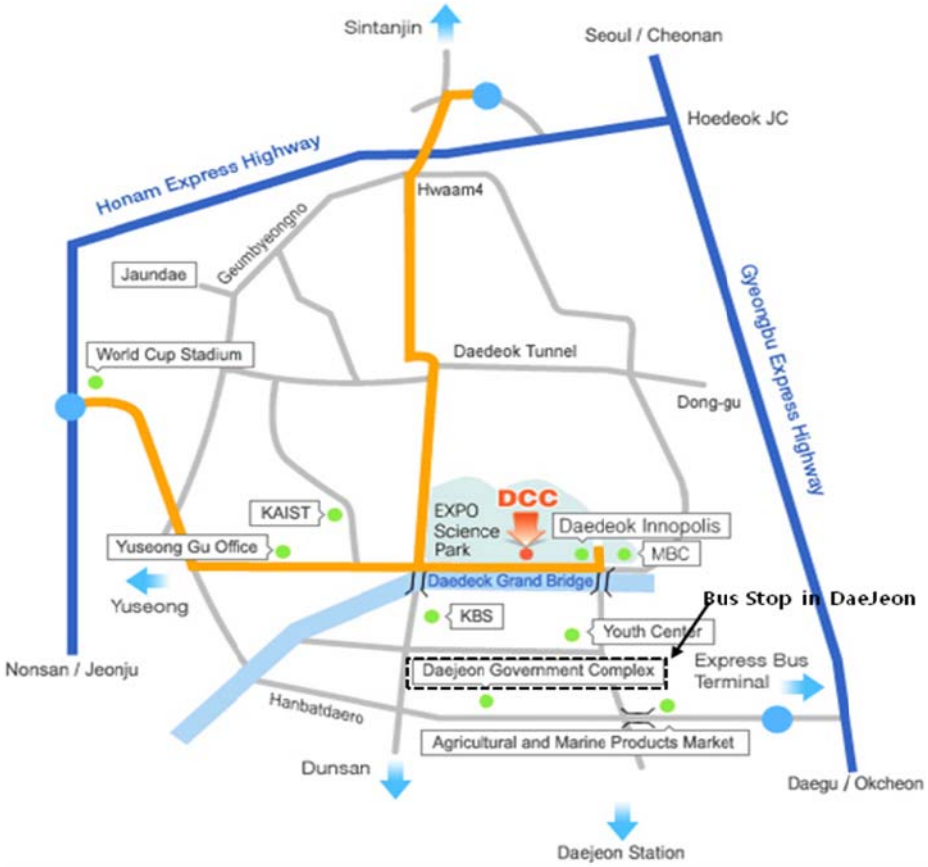
< Resources : Incheon Int'l Airport WEBSITE >

Bus Stop	Time	Duration	Fee	Station
1st Floor 9D	06:20 AM ~ 02:40 AM	180~200 min	KRW 22,100 (regular) KRW 24,300 (late night)	Daedeok Lotte Hotel, Daejeon Government Complex, Dongboo Cross-Country Bus Terminal Center

From Incheon Airport to DCC



How to get to DCC in Daejeon



The Korean-Australian Rheology Conference 2011

September 25 ~ 27, 2011, DAEJEON CONVENTION CENTER, Daejeon, Korea

CONFERENCE SCHEDULE

September 25 (Sunday), 2011

18:00 ~ 20:00 Welcome Reception & Registration

September 26 (Monday), 2011

08:30 ~ 09:00 Registration
09:00 ~ 09:20 Opening Ceremony
09:20 ~ 10:00 Plenary Lecture 1
10:00 ~ 10:30 Coffee Break
10:30 ~ 12:20 Session 1
12:20 ~ 14:00 Lunch
14:00 ~ 15:30 Session 2/SPE Korea Session 1
15:30 ~ 16:00 Coffee Break
16:00 ~ 17:00 Session 3/SPE Korea Session 2
17:00 ~ 18:00 Poster Session
18:30 ~ 20:30 Conference Dinner

September 27 (Tuesday), 2011

09:00 ~ 09:40 Plenary Lecture 2
09:40 ~ 10:00 Coffee Break
10:00 ~ 12:10 Session 4
13:00 ~ 18:00 Excursion (Baekje Cultural Land)

September 26, 2011

PLENARY LECTURE 1

Room 105/106
Chair: Prof. Peter J. Scales (The University of Melbourne)

Time	No.	Speaker	Title
09:20-10:00	**PL1**	Jae Ryoun Youn	**Deformation of Injection Molded Electric Connectors** Seoul National University

Session 1

Session 1-A (General Rheology) / 10:30 ~ 12:20 **Room 101**
Chair: Prof. Satinath Bhattacharya (RMIT University)

Time	No.	Presenter	Title
10:30-11:00	**KL1**	J. Ravi Prakash	**Concentration dependent dynamics of semi-dilute DNA solutions** Monash University
11:00-11:20	**A1**	Eun Kyoung Park	**Interesting rheological properties of pluronic F127 copolymer solutions and gels** Pusan National University
11:20-11:40	**A2**	Anthony D. Stickland	**The effect of compressional load on shear yield stress** University of Melbourne
11:40-12:00	**A3**	Sang Hyuk Lim	**Yield and flow measurement of fine and coarse binary particulate mineral slurries** Seoul National University
12:00-12:20	**A4**	David I. Verrelli	**Influences of normal stress differences on measurements of yield stress** CSIRO

Session 1-B (Polymer Processing) / 10:30 ~ 12:20 **Room 102**
Chair: Prof. Rahul K.Gupta (RMIT University)

Time	No.	Presenter	Title
10:30-11:00	**KL2**	Ying-She Luo	**The experimental research on the pyromagnetic effect of PVC sheet with defects** Central South University of Forestry and Technology
11:00-11:20	**B1**	In Chul Um	**The effect of rheological properties on the wet- and electro-spinning of regenerated silk solution** Kyungpook National University
11:20-11:40	**B2**	Ji Won Hwang	**Relaxation of colloidal drops in drying stage via multi-speckle diffusing wave spectroscopy (MSDWS)** Korea University
11:40-12:00	**B3**	Yang Ho Na	**Mechanical response to electric stimulation in chiral smectic liquid crystal elastomer** Hokkaido University
12:00-12:20	**B4**	Wen Ling Zhang	**Graphene oxide-polymer composites and their electrorheological characteristics** Inha University

Session 2

Session 2-A (Polymer Melts & Solution) / 14:00 ~ 15:30 **Room 101**
Chair: Prof. J. Ravi Prakash (Monash University)

Time	No.	Presenter	Title
14:00-14:30	**KL3**	Hiroshi Watanabe	**Component dynamics in miscible polymer blends** Kyoto University
14:30-14:50	**A5**	Siyoung Choi	**Microrheology of phospholipid monolayers with and without cholesterol** University of California, Santa Barbara
14:50-15:10	**A6**	Florian J. Stadler	**Correlations between molecular structure and terminal rheological properties in long-chain branched metallocene catalyzed polyethylene** Chonbuk National University
15:10-15:30	**A7**	Gun Woo Park	**Micro-mechanical modeling of ideal networks: from the mechanical properties of constituents to those of the system** Kyungpook National University

Session 2-B (Suspension and Colloids) / 14:00 ~ 15:30 **Room 102**
Chair: Dr. Myung Suk Chun (KIST)

Time	No.	Presenter	Title
14:00-14:30	**KL4**	Satinath Bhattacharya	**Role of extensional rheology in polymer blends and composites** RMIT University
14:30-14:50	**B5**	Hye-Jin Ahn	**Fundamental rheological investigation of snail secretion filtrate as a main ingredient of cosmetic creams and lotions** Pusan National University
14:50-15:10	**B6**	Jianjun Guo	**Current density response of polar molecule dominated electrorheological fluids** Chinese Academy of Sciences
15:10-15:30	**B7**	Ramesh Subramanian	**Effect of heating and cooling on rheology of reduced-fat cheese** Laurentian University

Session 3

Session 3-A (Polymer Melts & Solution) / 16:00 ~ 17:00 **Room 101**
Chair: Prof. J. Ravi Prakash (Monash University)

Time	No.	Presenter	Title
16:00-16:20	**A8**	Hua-Yong Liao	**Experimental studies on rheological behavior of PP/PA6 blends** Changzhou University

Time	No.	Presenter	Title
16:20-16:40	**A9**	Esmaeil Narmissa	**Morphological and rheological characterization of PLA/NGP biocomposites** RMIT University
16:40-17:00	**A10**	Kwang Soo Cho	**Nonlinear iterative algorithm for relaxation time spectrum** Kyungpook National University

Session 3-B (Suspension & Collioids) / 16:00 ~ 17:00 **Room 102**
Chair: Dr. Myung Suk Chun (KIST)

Time	No.	Presenter	Title
16:00-16:20	**B8**	Rahul K. Gupta	**Rheology and laminar-turbulent transition prediction of highly concentrated fly ash slurries** RMIT University
16:20-16:40	**B9**	Ying Dan Liu	**A unique kind of electrorheological material: conducting polymer incorporated core-shell structured composite particles** Inha University
16:40-17:00	**B10**	Fuzhong Qi	**Random close packing and relative viscosity of bimodal suspensions** University of Sydney

September 27, 2011

PLENARY LECTURE 2

Room 105/106
Chair: Prof. Jae Ryoun Youn (Seoul National University)

Time	No.	Speaker	Title
09:00-09:40	**PL2**	Peter J. Scales	**A multi-dimensional description of the deformation and flow of concentrated particulate suspensions under combined shear and compressive forces** The University of Melbourne

Session 4

Session 4-A (Micro/Nano Rheology) / 10:00 ~ 12:10 **Room 101**
Chair: Prof. Hyun Wook Jung (Korea University)

Time	No.	Presenter	Title
10:00-10:30	**KL5**	In Seok Kang	**Electrically driven microdroplets in a dielectric liquid as biochemical reactors** Pohang University of Science and Technology
10:30-10:50	**A11**	R. Prabhakar	**ADMiER-ing active fluids** Monash University

Time	No.	Presenter	Title
10:50-11:10	**A12**	Woojoo Han	**Flow instability and in-situ pressure fluctuation of concentrated suspensions in capillary flow** Seoul National University
11:10-11:30	**A13**	Rinbok Wi	**Formation of liposome by microfluidic flow focusing and its application in gene delivery** KAIST
11:30-11:50	**A14**	Kyoung G. Lee	**Artificial biofactory for mass production of metal nanoparticles using the combination of cell extracts and droplets in a microfluidic device** KAIST
11:50-12:10	**A15**	Kwang Seok Kim	**Correlations between fluid slippage and oscillating pressure pulsation in electrokinetic microflows** Korea Institute of Science and Technology (KIST)

Session 4-B (Computational Rheology) / 10:00 ~ 12:10 **Room 102**
Chair: Prof. Seong Jae Lee (The University of Suwon)

Time	No.	Presenter	Title
10:00-10:30	**KL6**	Dong Sup Kim	**Energy Challenges and Technology: Rheology for battery Industry** SK Innovation
10:30-10:50	**B11**	Tae Gon Kang	**Direct numerical simulation of the magnetoviscous effect in simple shear flow** Korea Aerospace University
10:50-11:10	**B12**	Tae Won Seo	**Physiological blood flow in coronary arteries** Andong National University
11:10-11:30	**B13**	Jeong Yong Lee	**Microrheological study on submicron sized wormlike polyelectrolyte chain in flow fields via simulations and single molecule tracking** Korea University
11:30-11:50	**B14**	Wook Ryol Hwang	**Flow modeling of complex fluids in advanced composite manufacturing** Gyeongsang National University
11:50-12:10	**B15**	Sung-Up Choi	**A numerical study on three dimensional 4:1 contraction channel flow of aggregating particulate suspension** Seoul National University

POSTER SESSION

September 26 (Monday), 2011
17:00 ~ 18:00, 1F Lobby

No.	Presenter	Title
P1	Tae Gyeong Kang	**Simultaneous detection of multiple mutations in epidermal growth factor receptor based on fluorescence quenching of quantum dots** Yonsei University
P2	Kyung YI Kim	**Long chain branch effect of In-situ PP/PVA blend and nanocomposite for food packaging** Sogang University
P3	Sung Hun Kim	**Characterizations of magnetic powder mixtures for the magnetic PIM** POSTECH
P4	Jin Ho Kim	**Experiment studies on flow characteristics and instability of various paints in 3-roll coating process for automotive pre-painted metal sheets** Korea University
P5	Kyun Joo Park	**Preparation of E. coli encapsulated monodisperse microdroplets by organoclay-assisted interfacial polymerization in a microfluidic device** KAIST
P6	Jae Kyoung Yang	**The characteristics of electron beam crosslinked polyamide-12 /clay nanocomposites** Sogang University
P7	Seong Jae Lee	**Microcellular nanocomposite foams having electrical conductivity by polymerized high-internal phase emulsions** The University of Suwon
P8	Si Hyung Lee	**Effect of slot die geometry on 2-d slot coating flow** Korea University
P9	Yun Kyun Lee	**Effects of double percolation structure on the rheological percolation thresholds** Korea University
P10	Hyunjung Lim	**Size-based microparticle separation using elasto-inertial effect of non-Newtonian fluid** Korea University
P11	Kwang Ho Jang	**Quantitative analysis of dispersion state of EVA nanocomposite** Sogang University
P12	Kyu Hyun	**A non-linear parameter Q from FT-rheology under LAOS flow for polymer composite system** Pusan National University
P13	Dae-Hyun Hwang	**Improvement of quantum dots dispersion for high luminescent efficiency of QD/PDMS coating** Yonsei University
P14	Tae Yong Hwang	**Rheology and electrical conductivity of immiscible PP/PS blends with MWCNT** Sogang University

No.	Presenter	Title
P15	Eun Jeoung Lee	**Temperature-dependent rheological properties of linter-based cellulose solutions in NMMO monohydrate** Hanyang University
P16	Won-Sik Bae	**The effects of dissolution conditions on the rheological properties of polyolefin ketone spinning dope in an aqueous solution of complex metal salts** Hanyang University
P17	Jeong Sik Bae	**Effects of shearing on crystallization of aliphatic polyketone** Hanyang University
P18	Jip Kim	**The rheological properties of poly(olefin ketone) solution in an aqueous solution of complex metal salts** Hanyang University
P19	Young Ho Eom	**Effects of solubility on the rheological properties and gelation process of polyacrylonitrile solutions in DMF and DMSO** Hanyang University
P20	Zhen-Yu Li	**Testing study and modeling analysis of rheological characteristic of Nanning expansive soil** Cental South University of Forestry and Technology
P21	Xiangfang Peng	**Effects of vibration force field on the extensional stress of HDPE in slit die** South China University of Technology
P22	Qing Chen	**Texture properties of high acyl gellan gels** Zhejiang Gongshang University
P23	Sen Wang	**Effect of different salt conditions on texture properties of almond gels** Central South University of Forestry and Technology
P24	Zhi-Xin Yan	**Study on mechanical action and its effects of slope vegetation** Lanzhou University
P25	Yuchuan Cheng	**The size effect on the electrorheologcial suspension** Chinese Academy of Sciences
P26	Jin-Wei Chen	**Batch foaming biodegradable polylactide/montmorillonite and polylactide/sericite composites** Guangdong Industry Technology College
P27	Hyun Jung Koh	**Operability windows of generalized Newtonian slot coating flows using 1-D and 2-D models** Korea University
P28	Min-Sun Kwak	**Rheological comparison of cosmetic creams and lotions in actual application conditions** Pusan National University

No.	Presenter	Title
P29	Jae Hee Kim	**Nonsymmetric response of viscoelastic fluids under dynamic squeeze flow** Seoul National University
P30	Yang-In Lee	**Nonlinear Rheological Properties of Unsalted and Spreadable Butters** Pusan National University
P31	Young Ki Lee	**Mesoscale simulation approach to study colloidal-gelation in immiscible fluid mixture** Seoul National University
P32	Ji-Seok Lee	**Abnormal rheological properties of carbopol 940 in aqueous media** Pusan National University
P33	Hyung Tag Lim	**Electrical properties of multi-walled carbon nanotube/polymer composites aligned by electric field** Seoul National University
P34	Jung-Eun Bae	**Model calculations for large amplitude oscillatory shear for the investigation of origin of strain-frequency superposition** Kyungpook National University
P35	Mi-Kyoung Kwon	**A study on linear viscoelasticity of blends of immiscible polymers** Kyungpook National University
P36	Baiping Xu	**The simulation and characterization of mixing performance in novel co-rotating non-twin screws** Guangdong Industry Technical College
P37	Myung-Ho Kim	**Novel and alternative method of measuring polymer melt viscosity: the Screw Rheometer** Hannam University
P38	Yue-Jun Liu	**Loss angle testing of polymer melts at high shear rate** Hunan University of Technology
P39	Tahmineh Mahmoudi	**Vinyl ester/carboxy terminated butadiene/styrene compounds can cause shear Induced gelation due to physical temporary networks** Chonbuk National University
P40	Nick A.T. Miller	**Temperature profile for nanofluidic flows of colloids** RMIT University
P41	R. Prabhakar	**Constitutive modeling of self-concentrating “dilute” polymer solutions** Monash University

SPE Korea Session

September 26 (Monday), 2011

SPE Korea Session 1 (Rheology for Industrial Applications)/ 14:30 ~ 15:30 **Room 103**
Chair: Dr. Woo Jin Choi (Korea Research Institute of Chemical Technology)

Time	No.	Presenter	Title
14:30-14:50	**S1**	Yu-taek Sung	**Rheological Characterization of Metallocene Polyethylene** LG Chem.
14:50-15:10	**S2**	P. J. Yoon	**Rheology as an Evaluation Tool of Nanoparticle Dispersion** Shinil Chemical Ind.
15:10-15:30	**S3**	Myung Wook Kim	**Chain Extension Effects on Crystallization and Biodegradability of PLA/PBT Blend** Honam Petrochemical Corp.

SPE Korea Session 2 (Rheology for Industrial Applications)/ 16:00 ~ 17:00 **Room 103**
Chair: Dr. Woo Jin Choi (Korea Research Institute of Chemical Technology)

Time	No.	Presenter	Title
16:00-16:20	**S4**	Youngjae Yoo	**Multiphase Polymer Nanocomposites** Korea Research Institute of Chemical Technology
16:20-16:40	**S5**	Sun Kyoung Kim	**Flow Instability of Polypropylene Melt in Micro-injection Molding** Seoul National University of Science & Technology

6th KOREAN–AUSTRALIAN RHEOLOGY CONFERENCE 2011

Influences of Normal Stress Differences on Measurements of Yield Stress

항복 응력의 측정에 대한 수직 응력 차이의 영향

Dr. David I. Verrelli
Postdoctoral Fellow
26 September 2011

CSIRO

Acknowledgements

The Australian Society of Rheology
- Howard See Young Rheologist Travel Award

The University of Melbourne
- Prof. Peter J. Scales
- Dr. Jonathan Foong
- Mr. Adam R. Kilcullen
- Prof. David Boger

CSIRO Process Science and Engineering
- Dr. Marcus D. Zipper
- Dr. Andrew Chryss

CSIRO Materials Science and Engineering
- Dr. Russell Varley

Howard See: 1963–2010

Howard See in front of Sydney Harbour Bridge on conference excursion from 5th KARC (04 November 2009)

KARJ, Vol. 22, No. 3, September 2010

Summary

1. Simplicity is nice
2. Rheological models simplify rheological behaviour
3. Real rheological behaviour is not always simple
4. Rheological behaviour is not nice?

Hypothesis

Presence of normal stress differences would lead to misestimation or misinterpretation of the yield stress

Principle:

1. The **motion** of the material as the sample **deforms** first elastically and then plastically in the measurement apparatus sets up **normal stresses differences**.
2. The existence of the normal stress **changes** the level of shear stress that may be endured before **yielding**.

Significance depends on:

- amount of shear strain
- how quickly normal stress differences are established
- magnitude of the normal stress differences
- sensitivity of the yield stress to normal stresses

Yield stresses

Maxwell [1872] elegantly distinguished a solid from a fluid:

> When [...] **continuous alteration of form** is only produced by **stresses exceeding a certain value**, the substance is called a **solid**, however soft it may be. When the **very smallest stress**, if continued long enough, will cause a **constantly increasing change of form**, the body must be regarded as a viscous **fluid**, however hard it may be.

More generally, we can describe behaviour
below the **yield stress** as 'solid-like'
and behaviour
above the **yield stress** as 'fluid-like'

Yield stresses can also be interpreted as a transition to extremely high (practically infinite) viscosity

Common for particulate suspensions

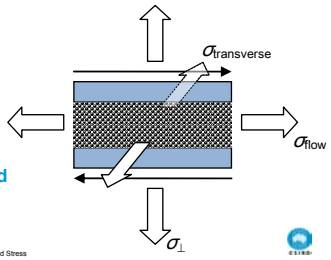
Normal stress differences

Normal stress differences (NSD's) refer to 'extra' normal stress beyond the isotropic pressure

They arise because of deformation

Well known from

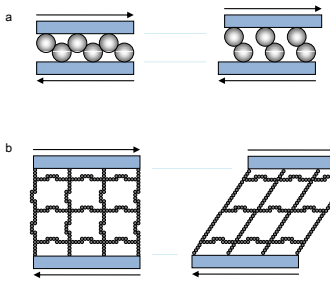
- the Weissenberg effect seen with **polymers**
- shearing of **granular material**



Also occurs with aggregated colloidal particle networks

Normal stress differences

Response of two different particle systems to shear.



Cohesionless granular array.

Colloidal particulate network formed by aggregation.

Normal forces are not shown.

It is assumed that wall slip is absent.

Different to other systems

- NSD in polymer solutions due to conformational changes and alignment
  - NSD is a strong function of shear strain *rate*
- NSD in granular systems due to 'steric' effects
- NSD in colloidal particle networks due to maintenance of 'force chains'
  - can maintain orientation even at zero shear strain rate
  - function of applied shear *strain* (or shear *stress*)

Applications

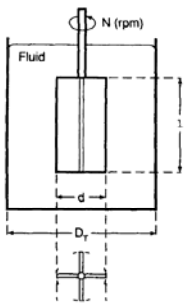
- Paste transport
  - yield stress affected by normal stress differences under dynamic flow
  - value not same as for yielding of intact sample
- Mixing problems
  - *e.g.* dead zones
- Thickeners
  - dead zones
  - shut-down / start-up
- Composites
  - control over 'whisker'/particle orientation [Doraiswamy et al., 1991]
  - limiting size of unsupported 'green' body

Knowledge gap

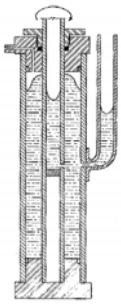
- There are numerous studies of *yield stresses* and of *normal stress differences* **separately**
- There is little or no consideration of the **coexistence** of these two phenomena
- For example, consider the common fluid models available
  - Oldroyd-B, FENE-P, Reiner–Rivlin, power-law, ...
  - Bingham, Casson, Herschel–Bulkley, ...

Comparison: vane *versus* Couette

Vane configuration
[Nguyen & Boger, 1992]



Normal stresses in circular Couette flow [Markovitz, 1967]

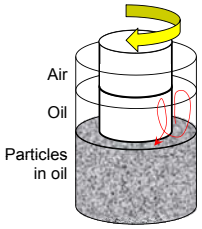


Can ‘rod climbing’ be seen in particle systems?

- In polymer systems (*e.g.* polyisobutylene solutions), rod climbing (Weissenberg effect) is characteristic of normal stress differences
- In aggregated /granular systems the NSD’s operate through the colloidal network /force chains
  - do not operate through the fluid
  - fluid provides buoyancy
- Experiment
  - wide-gap Couette
  - attempt to maintain buoyancy
    ∴ near neutrally-buoyant particles
  - viscous carrier fluid

  ...inconclusive

  obtained Taylor-type vortices at *Re* ~ 8 (*cf.* threshold of 100–800)



Oscillatory data — with simplifying assumptions

Asymptotic behaviour:

$$\lim_{\dot\gamma\to 0}\Psi_1(\dot\gamma) \equiv \lim_{\dot\gamma\to 0}\frac{N_1(\dot\gamma)}{\dot\gamma^2} = \lim_{\omega\to 0} 2\frac{G'(\omega)}{\omega^2}$$

$$\lim_{\dot\gamma\to 0}\eta(\dot\gamma) = \lim_{\omega\to 0}\eta'(\omega) \equiv \lim_{\omega\to 0}\frac{G''(\omega)}{\omega}$$

Stated to be valid for “simple liquids” [Larson, 1999].

Given $\tau = \eta\dot\gamma$

obtain ratio of first normal stress difference / shear stress

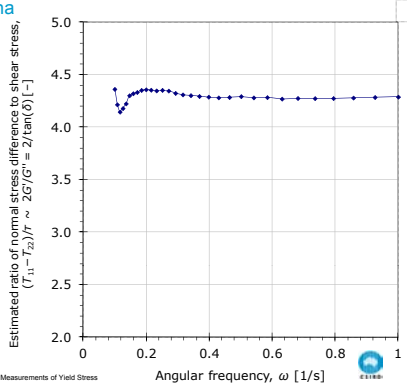
$$\lim_{\dot\gamma\to 0}\frac{N_1(\dot\gamma)}{\tau} = \lim_{\omega\to 0} 2\frac{G'(\omega)}{G''(\omega)} \equiv \lim_{\omega\to 0}\frac{2}{\tan\delta}$$

Oscillatory data — with simplifying assumptions

Destabilised α-alumina
- diameter ~ 180 nm
- 25 % solidosity
- at i.e.p. (pH = 9.2)

Rheometry by J. Foong [2007, unpub.]

Normal stress difference ≈ 4 × Shear stress



“ Six of one, half a dozen of the other ”

If you believe those results...
...then we agree that *normal* stresses may interfere with *yield* stress measurement

If you do not believe those results...
...then we agree that *yield* stresses may interfere with *normal* stress measurement

Oscillatory data — detailed model

Use elastic–viscoplastic model of Doraiswamy *et al.* [1991]

- below critical yield strain (below yield stress), *elastic* behaviour
  - Hooke model
  - fully recoverable
- above critical yield strain, *viscous* behaviour
  - Herschel–Bulkley model
  - only residual elastic deformations are recoverable

Hence proposed extension/analogy to Cox–Merz rule for yield-stress materials using “effective shear rate” $\gamma_0\,\omega$
(“Rutgers–Delaware rule”)

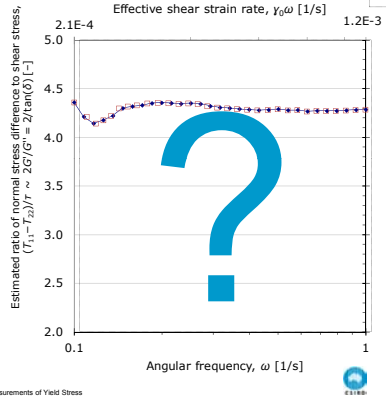
Oscillatory data — *ad hoc* analysis

Destabilised α-alumina
- details as before

Replace ω with $\gamma_0\omega$

Rheometry by J. Foong [2007, unpub.]

Normal stress ≈ 4 × Shear stress



Oscillatory data — detailed model

Same data as before — solve for model parameters

- *elastic* contributions (Hooke model)
  - critical shear strain, γ_c ~ 0.001 (Foong value: 0.0016)
  - shear modulus, G ~ 840 000 Pa
  - **shear yield stress, τ_y ~ 820 Pa**
    (Foong values: vane ≈ 300 Pa, critical ≈ 650 Pa, dynamic ≈ 710 Pa)
- viscous behaviour (Herschel–Bulkley model)
  - power-law coefficient, K ~800 Pa.s 'consistency'
  - power-law index, n ~0.05
    (*cf.* ~0.1 for skin cream, lubricating grease [Barnes *et al.*, 1989, p.22])

Model scenario: oscillatory shear up to critical strain, $\gamma_{max} = \gamma_c$

- **Estimated *normal* stress** **~410 Pa** $= G \max\{\gamma_{11}^{[0]}\}$
  ~820–1230 Pa $= E \max\{\gamma_{11}^{[0]}\}$
  comparable to shear yield stress
- Estimated viscous *shear* stress ~1500 Pa $= \max\{\eta\} \max\{\dot{\gamma}_{12}^{[0]}\}$

Concluding remarks

- Reality is not simple
  - "yield stress" materials exhibit elasto-visco-plastic behaviour
  - few models account for this
  - few people use those few models
- Yield stresses and normal stress differences can occur together
- Consider aggregated colloidal networks
  - typical of above behaviour
  - different from other systems — polymeric; granular
- NSD's may influence 'effective' yield stress — and *vice versa*
  - potential measurement interference
  - 'effective' yield stress may vary in different flow scenarios

Dr. David I. Verrelli

Postdoctoral Fellow
CSIRO Process Science and Engineering

Phone: +61 3 9545 8689
Email: David.Verrelli@csiro.au
Web: www.csiro.au/org/Mineral-Processing.html

formerly at
The University of Melbourne

Member of
The Australian Society of Rheology council

www.csiro.au

감사합니다

Contact Us
Phone: 1300 363 400 or +61 3 9545 2176
Email: enquiries@csiro.au Web: www.csiro.au