THE PARTICLE TECHNOLOGY FORUM (PTF) NEWSLETTER

An American Institute of Chemical Engineers (AIChE) Forum

A Glance at the Newsletter

Editorial

Dear Fellow PTF Members, I hope this newsletter finds you

in good physical, emotional, and mental health amidst the ongoing global health crisis. Our hearts go out to the victims of COVID-19, and their families and friends. Hats off to everyone on the front lines during this crisis!! Although we

Message from the Chair

Greetings to all my PTF colleagues from the comfort of my nominal "home office." I hope this newsletter finds all of you in good health and that you are all working and living safely during our current health crisis with COVID-19. We have found already that it is impacting our lives and schedules, but hopefully will be cleared up by this fall.

As many of you may have seen, the Spring AIChE meeting and the 2020 Frontiers in Science & Technology symposium have been postponed to the week of August 17th. They will still be in Houston, and the program looks like it is intact despite the change in dates. The good news is that it gives even more of you the chance to attend this exciting symposium on "Designed Particles" and how engineering for particle design impacts the product as well as the process.

Otherwise, our spring activities keep chugging along. We are setting up the sessions for the Annual meeting in San Francisco this November. Please submit your abstracts and titles for the sessions that you want to participate in by April 30th.

The PTF Awards nominations are quickly coming up on us. Additionally, award nominations for the various PTF awards are in full swing. Please go to the PTF webpage to look at are living in unprecedented times, this temporary phase will pass, and we will come out stronger than ever. We must continue playing our roles sincerely in slowing down the spread of COVID-19 by maintaining social distancing and practicing food hygiene.

"Danger gathers upon our path. We cannot afford — we have no right — to look back. We must look forward." – Winston Churchill

As you may be aware, several conferences, including the 2020 AIChE Spring Meeting and 2020 Frontiers in Particle Science and Technology (FPST) Meeting, have been postponed to a later date. This newsletter includes some of those changes, key highlights from the 2019 AIChE Annual Meeting, contributions from the 2019 AIChE PTF award recipients, nomination request for 2020 AIChE PTF awards, call for nominations for the Executive Committee (EC) elections, and more.

If you would like to contribute to the 2020 Summer newsletter, please contact me as soon as possible with your idea.

"Optimism is the faith that leads to achievement. Nothing can be done without hope and confidence." – Helen Keller

Stay safe!! Stay healthy!! Stay strong!! Stay positive!!

Mayank Kashyap, SABIC

Editor

PTF Newsletter

the nomination process and forms (https://www.aiche.org/community/sites/divisions-forums/ptf/awards). Jim Gilchrist has an article in this newsletter explaining the deadline and where to send the nominations. Please note the deadline for the nomination packages. As with last year, we will have a single round of nominations and the award committees with select from those prepared. There are many awards and I am sure many deserving candidates for these awards so please do your part and nominate someone!

Finally, this is an election year for the Executive Committee Leadership of the PTF. Two Academic Liasons will be elected, along with two Industrial Liasons. If you are interested in serving as a Liason to the EC, please see either the article about elections written by Michael Molnar, or see the email sent to all PTF members from Michael in early April. This is also the year that a new Vice-Chair is selected from prior Liasons (according to the bylaws) by the EC. This year the vice-chair to be elected will be an industrialist. Jim Gilchrist will assume the chairmanship after the Annual Meeting.

In closing, we are certainly living in interesting times. I remember as a child my parents and grandparents telling me stories of the Great Depression and World War II, and asking an elderly friend about her childhood in the 1880's before there were any automobiles. Their stories were amazing to me. This year is one of those seminal occasions that we will describe to our children and grandchildren as a critical time in our world's history, and how we as a world rose to the occasion to overcome and survive. Politics aside, we will overcome and survive. And Chemical Engineering and Particle Technology will be at the frontier of discovery in defeating this viral challenge.

Stay Safe, Stay Healthy, and we look forward to seeing most of you later this year!

Regards,

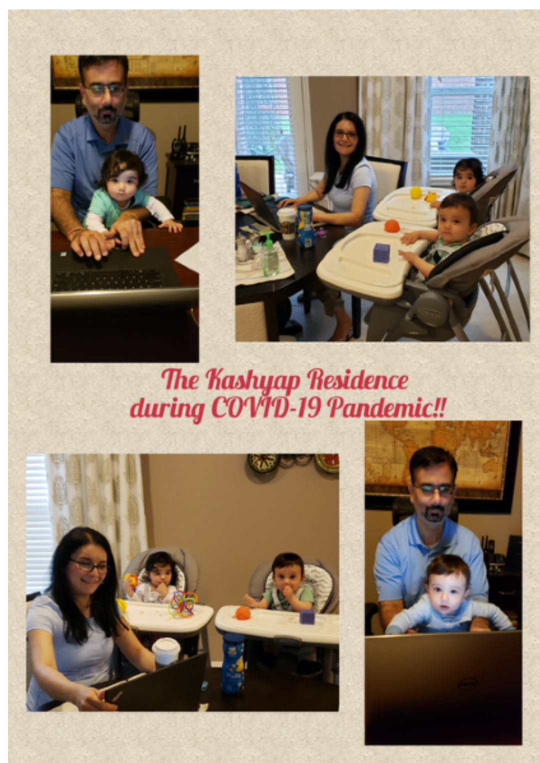
Bruce D. Hook, The Dow Chemical Co.

Chair,

Particle Technology Forum

Working from Home: Are We Counting Challenges or Blessings?

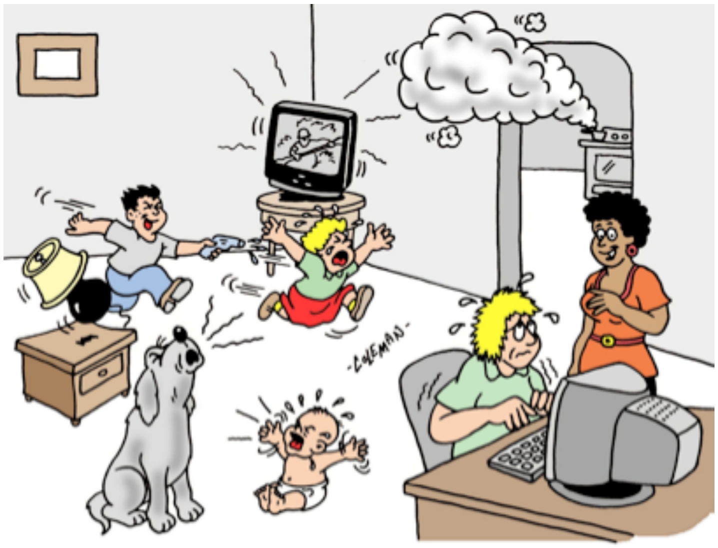
The ongoing COVID-19 pandemic has restricted millions of people around the globe from going to their work places in the past several weeks. On one hand, there is no denying that the sudden and unexpected changes in the daily routine, like many changes do, have brought certain challenges in our lives. While the employers are worried about employee productivity, the employees may be feeling that they have to work all the time in order to demonstrate they are staying productive. This could potentially merge afternoons into evenings, and weekdays into weekends, with little sense of time off during the days, weeks, or even months to come. Ironically, some of us might be missing the "peak-hour" commute to and fro work place that earlier used to bring anxiety, as the commute has now reduced to only walking from the bedroom to home office to other areas of the house. What about coffee breaks at the office lunchrooms that often involved catching up with colleagues on professional and personal levels? And a roughly 40% increase in the time we now get to spend (happily) with the family in a week must be a welcome change, right? In addition, the closure of many schools and daycares puts additional burden on working parents, who now have to take care of the kids while working from home. Furthermore, weekends no longer mean we could fulfill self-actualization needs to carry out social activities, including visits to the parks, movie or play theaters, shopping malls, etc.



On the other hand, without drawing parallels between the current situation and a famous proverbial phrase, *glass half-full or half-empty*, one could argue that blessings should also be counted during these tough times. For example, a lot of us have been fortunate to make the transition to working from home amidst the tightened social-distancing restrictions, whereas, several front line workers from essential industries do not have such luxury. In addition, receiving the opportunity to spend more time with the family might actually be a silver lining. Personally, the current changes have provided my wife and me with a priceless opportunity to strengthen the bond with our infant twins who are achieving significant milestones almost on a daily basis, in the first year of their lives.

Isn't it easier said than done?

While sitting in my office-away-from-office, I have decided to put together a few thoughts, highlighting key aspects of the new work-from-home lifestyle. It is quite possible that several employees may be asked to work remotely for several more weeks, if not months. Hence, it is critical that we avoid enduring risks associated with burnout. As the line



" IT MUST BE NICE HAVING A JOB WHERE YOU CAN WORK AT HOME. "

between work and home blurs, and as many of us who are working remotely for the first time (or even experienced folks) adjust to the new reality, it is important for us to preserve healthy boundaries between our professional and personal lives. Please find below a summary of some key recommendations from various sources that, in my opinion, should help us all to maintain good physical, mental and emotional health while we work from home[1,2].

Maintain physical and social boundaries

Ashforth et al. (2000) described how people separate the transition from work to home roles via boundary-crossing activities. Physical and social indicators, such as setting up the wake-up alarm, putting on work clothes, commuting from home to work, attending in-person meetings, etc., typically show that we have transitioned from "home us" to "work us". These indicators are now telling us that something is different these days. Hence, in order to maintain these boundaries in a healthy way in the current scenario, references like Giurge and Bohns (2020) suggest that we setup an alarm to wake up in the morning at a usual time, put on work clothes every morning rather than staying in pajamas the entire day, replace the morning commute with walking to a nearby park or just around the house while maintaining social distancing, before sitting down to work, etc.

Maintain temporal boundaries

While it may be quite challenging for employees without responsibilities of children or other family members to maintain temporal boundaries during regular work hours in the work-from-home environment due to the availability of mobile devices that keep them connected to work all the time, it is even more challenging for those with such responsibilities. The past several weeks have taught many of us that maintaining a regular work schedule may not be realistic under the current circumstances, especially when our team members are facing similar challenges in their own lives. Hence, we need to be creative in finding the optimum time-slots that work best for us, while being flexible and respectful of our collaborators. The key is to keep a sense of normalcy as much as possible during this disruption, without being too rigid with regards to the schedule.

Focus on our most important work

In my opinion, the philosophy of focusing on most important work should be practiced even under normal circumstances. However, this is especially the time to spend our energy on top-priority tasks. Spending a lot of time on immediate rather than important tasks could be counterproductive in the long run, even if the short-term benefits are visibly significant.

Manage expectations without feeling guilty

Times like these could lead to anxiety and second guessing one's own abilities to manage several things at a time, especially if it involves simultaneously taking care of dependent(s) while working from home. Remember, even the best multitaskers have been dealt with yet another task, which is probably one of the most difficult tasks of all, i.e. unexpected management of work and home concurrently for an unknown period of time. A prominent Child, Adolescent, and Family Psychologist, Emily W. King[3], recently gave a public service announcement to parents, emphasizing, "*What we are being asked to do is not humanly possible. There is a reason we are either a working parent, a stay-at-home parent or a part-time working parent. Working, parenting and teaching are three different jobs that cannot be done at the same time. It's not hard because you are doing it wrong. It's hard because it's too much. Do the best you can. When you have to pick, because at some point you will, choose connection. Pick playing a game over arguing about an academic assignment. Pick teaching your child to do laundry rather than feeling frustrated that they aren't helping. Pick laughing, and snuggling, and reminding them that they are safe. If you are stressed, lower your expectations where you can and virtually reach out for social connection. We are in this together to stay well. That means mentally well, too.*"

Summary

The past few weeks have touched us all in many facets of our lives. The year 2020 has already enhanced awareness of "catchy" phrases that have now become a part of our daily lives, such as social distancing, work-from-home, remote working, stay-home, etc. No one would deny that the new normal has brought certain challenges into our lives. However, I would like to emphasize that we must embrace the changes positively, as they may be staying here for a while, either continuously or intermittently. We must count the blessings while facing challenging during these tough times. Please follow the health and safety guidelines from trusted local and federal health officials, and avoid any distractions while working from home.

I am sharing a few COVID-19 related resources from World Health Organization without intending to endorse the content or the organization.

Stay safe!! Stay healthy!! Stay strong!! Stay positive!!

References:

1. Giurge, L.M., Bohns, V.K. 3 Tips to avoid WFH burnout. Harvard Business Review, 2020

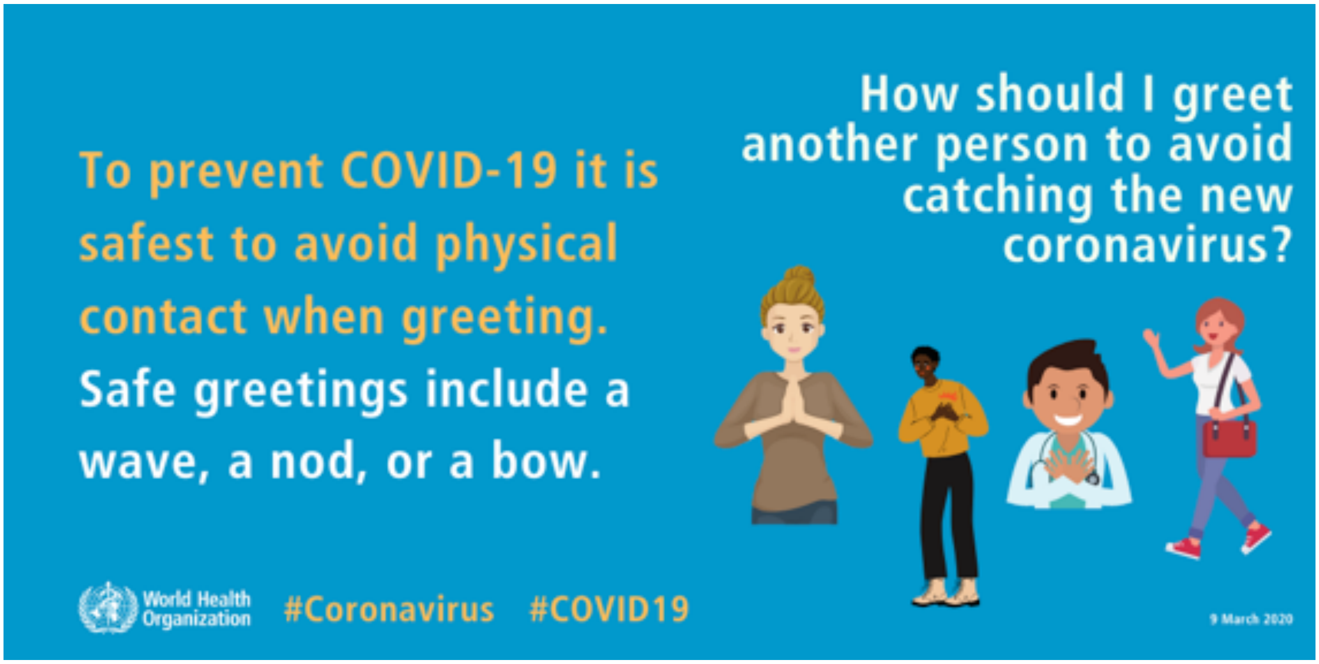
2. Ashforth, B.E., Kreiner, G.E., Fugate, M. All in a day's work: Boundaries and micro role transition. *The Academy of Management Review*. 25, 472-491, 2000

3. King, E.W. Parenting on your own path. Public Service Announcement on Facebook, 2020

- **Mayank Kashyap**

Staff Scientist - Corporate Technology & Innovation

SABIC

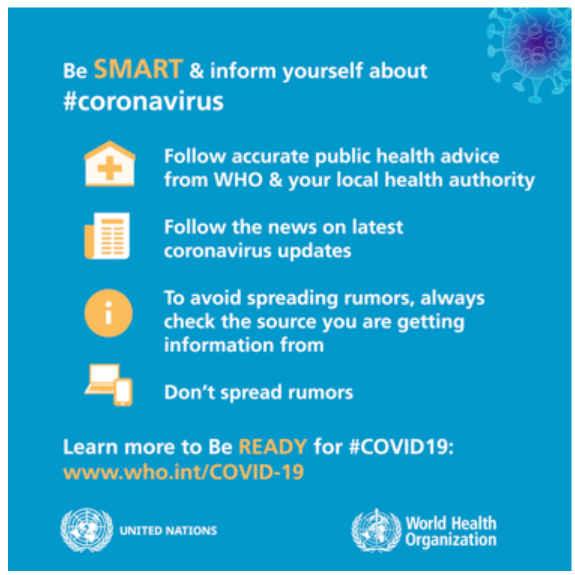

How should I greet another person to avoid catching the new coronavirus?
To prevent COVID-19 it is safest to avoid physical contact when greeting.
Safe greetings include a wave, a nod, or a bow.
World Health Organization
#Coronavirus #COVID19
9 March 2020

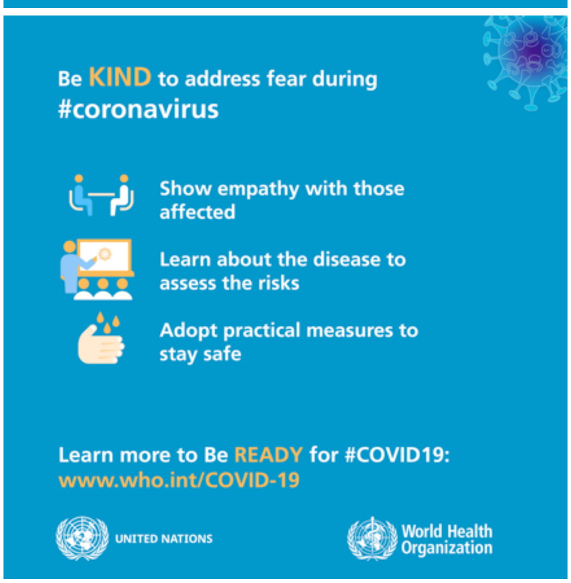

Be READY for #coronavirus
WHO is giving advice on how to protect ourselves & others:
Be SAFE from coronavirus infection
Be SMART & inform yourself about it
Be KIND & support one another
Learn more about #COVID19 & share with your loved ones: www.who.int/COVID-19
UNITED NATIONS
World Health Organization


Be SUPPORTIVE
Be CAREFUL
Be ALERT
Be KIND
Be READY to fight
#COVID19
For the latest health advice, go to:
www.who.int/COVID-19
UNITED NATIONS
World Health Organization


Be INFORMED
Be PREPARED
Be SMART
Be SAFE
Be READY to fight
#COVID19
For the latest health advice, go to:
www.who.int/COVID-19
UNITED NATIONS
World Health Organization


Be SAFE from #coronavirus
if you are 60+ or if you have an underlying condition like:
Cardiovascular disease
Respiratory condition
Diabetes
by avoiding crowded areas or places where you might interact with people who are sick.
Learn more to Be READY for #COVID19:
www.who.int/COVID-19
UNITED NATIONS
World Health Organization


Be SMART & inform yourself about #coronavirus
Follow accurate public health advice from WHO & your local health authority
Follow the news on latest coronavirus updates
To avoid spreading rumors, always check the source you are getting information from
Don't spread rumors
Learn more to Be READY for #COVID19:
www.who.int/COVID-19
UNITED NATIONS
World Health Organization

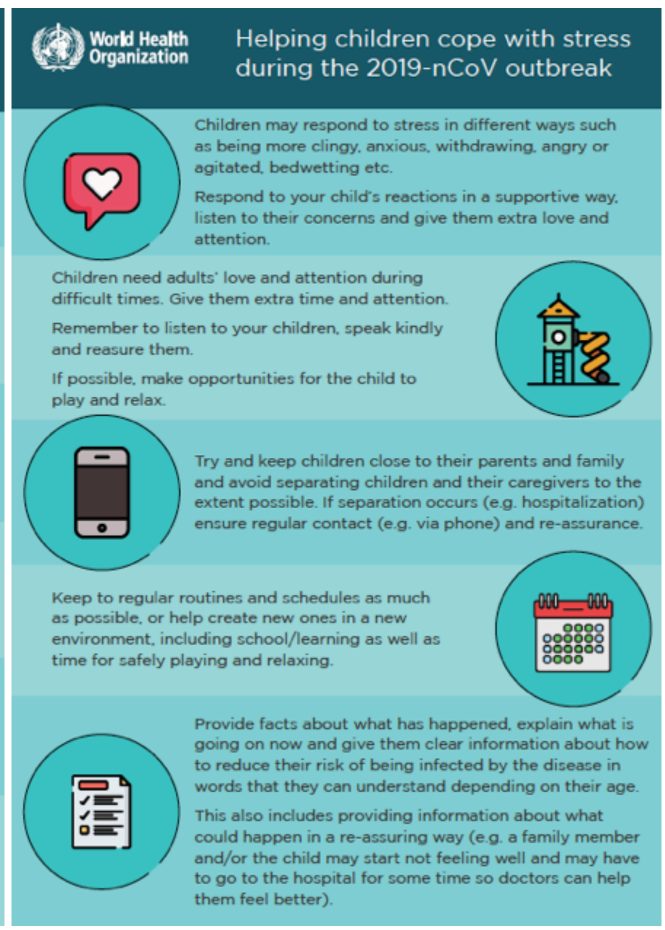

Be KIND to address fear during #coronavirus
Show empathy with those affected
Learn about the disease to assess the risks
Adopt practical measures to stay safe
Learn more to Be READY for #COVID19:
www.who.int/COVID-19
UNITED NATIONS
World Health Organization


Wash your hands
Wash your hands with soap and running water when hands are visibly dirty
If your hands are not visibly dirty, frequently clean them by using alcohol-based hand rub or soap and water
World Health Organization


Protect others from getting sick
When coughing and sneezing cover mouth and nose with flexed elbow or tissue
Throw tissue into closed bin immediately after use
Clean hands with alcohol-based hand rub or soap and water after coughing or sneezing and when caring for the sick
World Health Organization


Protect others from getting sick
Avoid close contact when you are experiencing cough and fever
Avoid spitting in public
If you have fever, cough and difficulty breathing seek medical care early and share previous travel history with your health care provider
World Health Organization


World Health Organization
Coping with stress during the 2019-nCoV outbreak
It is normal to feel sad, stressed, confused, scared or angry during a crisis.
Talking to people you trust can help. Contact your friends and family.
If you must stay at home, maintain a healthy lifestyle - including proper diet, sleep, exercise and social contacts with loved ones at home and by email and phone with other family and friends.
Don't use smoking, alcohol or other drugs to deal with your emotions.
If you feel overwhelmed, talk to a health worker or counsellor. Have a plan, where to go to and how to seek help for physical and mental health needs if required.
Get the facts. Gather information that will help you accurately determine your risk so that you can take reasonable precautions. Find a credible source you can trust such as WHO website or, a local or state public health agency.
Limit worry and agitation by lessening the time you and your family spend watching or listening to media coverage that you perceive as upsetting.
Draw on skills you have used in the past that have helped you to manage previous life's adversities and use those skills to help you manage your emotions during the challenging time of this outbreak.


World Health Organization
Helping children cope with stress during the 2019-nCoV outbreak
Children may respond to stress in different ways such as being more clingy, anxious, withdrawing, angry or agitated, bedwetting etc.
Respond to your child's reactions in a supportive way, listen to their concerns and give them extra love and attention.
Children need adults' love and attention during difficult times. Give them extra time and attention.
Remember to listen to your children, speak kindly and reassure them.
If possible, make opportunities for the child to play and relax.
Try and keep children close to their parents and family and avoid separating children and their caregivers to the extent possible. If separation occurs (e.g. hospitalization) ensure regular contact (e.g. via phone) and re-assurance.
Keep to regular routines and schedules as much as possible, or help create new ones in a new environment, including school/learning as well as time for safely playing and relaxing.
Provide facts about what has happened, explain what is going on now and give them clear information about how to reduce their risk of being infected by the disease in words that they can understand depending on their age.
This also includes providing information about what could happen in a re-assuring way (e.g. a family member and/or the child may start not feeling well and may have to go to the hospital for some time so doctors can help them feel better).

A Glimpse of the 2019 AIChE Annual Meeting - Orlando, Florida

Celebrating Frederick A Zenz's (1922-2018) Career Accomplishments

Dr. Frederick Zenz, 95, died on Wednesday, February 28th at Vassar Hospital.

Born on August 1, 1922 in New York City, Dr. Zenz began his illustrious career in 1942 with the M.W. Kellogg Co. as a process development engineer. Two years later, he began working for the Kellex Corporation on the MANHATTAN PROJECT during World War II. From 1946 to 1962, he worked for HRI, M.W. Kellogg and Stone & Webster Engineering. In 1962, he became an independent consultant. During his career, he also taught at Manhattan College, during which time he became the Technical Director of Particulate Solid Research, Inc. (PSRI), an industrial research consortium, from 1971 to 1989. He also founded and served as Technical Director of A.I.M.S. from 1989 and 2007. He authored at least 90 published papers, 18 book chapters, countless research papers for PSRI and A.I.M.S. and held 20 patents. In 1960, he co-authored one of the most influential books in engineering: Fluidization and Fluid-Particle Systems. His third and last book was published in 2015. He was named one of "30 Authors of Groundbreaking Chemical Engineering Books" and as one of the "100 Chemical Engineers of the Modern Era." He had a great passion for his field in engineering, coupled with a strong work ethic, working until the last weeks of his life.

He is survived by his wife of 69 years, Elizabeth; three children, Dennis, Jonathon and his wife Donna, and Terese and her husband Jim; nine grandchildren; and two great-grandchildren.

Session 292 - Special Session: Celebrating Career Accomplishments of Fred Zenz at AIChE Annual Meeting, Tuesday, November 12, 2019 - 8:00 AM - 10:30 AM at *Hyatt Regency Orlando - Bayhill 19*

Description

As the author of at least 90 published papers, 18 book chapters, and co-author of the influential "Fluidization and Fluid-Particle Systems", Dr. Frederick A. Zenz can be regarded as one of the pioneers in modern fluidization practice. In this special session, Dr. Zenz and his significant contributions were remembered and celebrated.

S.B. Reddy Karri

Dr. Zenz was a man of analogies. He liked to draw parallels from well-established relationships in the field of gas-liquid and apply them to the less-understood field of gas-solid systems. The statement, *"there exists an identity between the bulk or dense phase of macroscopic particulates and the "liquid" or dense phase of microscopic molecules. This "identity" results in a physical picturization of the "liquid" as simply molecules in a dense "packed bed" state"* is a testament to that. He developed several engineering tools based on this approach at PSRI.

He was also one of earlier pioneers who envisioned the existence of particle clusters in the fluidized bed and described the universe as clusters of galaxies. Even though I had spent little more than a year under his guidance, he became one of my mentors in my thinking about gas-solid systems. He loved cyclones all his life and consulted extensively in designing and trouble-shooting cyclones in the real world.

We surely miss his pioneering work in the area of fluid-particle systems.

Jon Zenz (Dr. Frederick Zenz's son)

One of the "professional" experiences I recall relating to Dr. Zenz is actually not a professional experience at all, but a memory that is occasionally brought up by my mother. The event (not that this occurrence was by any means an isolated case!) took place in the very early 1970s. The family home was a 200-year-old Victorian house with so many rooms that there was plenty of space in the basement for Dr. Zenz to partake in any mischief he desired. He also had four children and a wife who did all the household chores, leaving him time to spend 15 or so hours a day working endlessly at his profession. Failure to be productive and successful was not an option for himself and his wife, both of whom lost their fathers during the depression and whose financial stability at the outset was anything but assured.

It was against this backdrop that Dr. Zenz began doing hands-on experiments in the basement. Piecing together cold models of equipment using any combination of wood, plastic, steel etc., he built whatever he could to help demonstrate the operation (albeit in small scale) of whatever industrial equipment he was considering. He used an old blower to generate the gas flow, and he used a 0-40 cfm rotameter to meter it. I didn't have the heart to tell him that I had to discard the blower after it finally died around 2012. However, I believe I still have the rotameter.

In any event, one day he was testing some equipment, probably cyclones, and he ran the gas outlet up the cellar stairs and let it discharge onto the driveway. Not surprisingly, something occurred (likely related to the problem he was trying to solve) that resulted in heavy solids losses. Since the line was run to a point out of sight, he was not aware of what was happening until the loss of unit inventory became unavoidably apparent. By then, the driveway (and it wasn't small) was covered with a layer of FCC catalyst. I have vague memories of this incident, but I believe my older brothers and mother undertook the majority of the clean-up.

This type of work, albeit on a much larger scale, became the specialty of PEMMCORP beginning just a few years later and formed the basis of my engineering experience, operating PEMMCORP for about 25 years, as well as the basis for a relationship with Dr. Zenz. His ability to relate (often by inventive analogies) theoretical phenomena with everyday experience was a hallmark of his approach.

Roy Silverman

My first interactions with Fred Zenz were as a graduate student at Manhattan College, where he was my advisor. I found him to be always engaged in my concerns, and I never had a doubt that he had my best interests at heart. He gave me just enough freedom to explore my often-wacky ideas but kept the leash tight enough to prevent me from veering off in unproductive directions. I also worked at PSRI during that period, while Dr. Zenz was the Technical Director. In this capacity, the vast wealth of knowledge and experience he had was always there to be accessed by anyone on the job trying to solve a problem. After I left PSRI and Manhattan College, Dr. Zenz continued to be a professional mentor and valued advisor, as I got my career going.

My Professional Life with Fred Zenz – by Thomas F. McGowan, PE

I learned a lot from Fred, and still carry the knowledge around with me, using it daily. The density of air is 0.0765 lb_m/ft^3, there are 8.34 pounds per gallon of water, 7.48 cubic feet per gallon, 25,400 microns per inch, and any hole in the industry less than ¼" will plug. That and much more. He spoke of back-of-the-envelope calculations – I still do many, yes, do them on the back of a used envelope.

He sponsored me into Sigma Xi, the Scientific Research Society of North America, and suggested I buy a life membership (he was good with money) and lined me up to present my first AIChE paper at an annual meeting in Pittsburgh.

After leaving PSRI, we stayed in touch, he answered my occasional questions on the cuff and later asked me to review his books before publication. When I find an error, like spotting an inverted curve on a graph, he would exclaim "Golly! How did that happen!" He also worked for me on my fluidized bed projects, running numbers, checking my work, making sure we reached the right conclusions on the grid design.

I learned a lot from him while at PSRI, not just on engineering, but about how to navigate the world of work and business, and his consulting career made it easy for me to consider it as a career path.

Session in Honor of Prof. Atsushi Tsutsumi's Accomplishments

PTF Awards and Dinner


Ansys Particle Technology
Service Award:
Dr. Robert Pfeffer
Arizona State University
Sponsored by:
ANSYS


in Fluid-Particle Systems:
Dr. Aibing Yu
Monash University
Sponsored by:
Shell

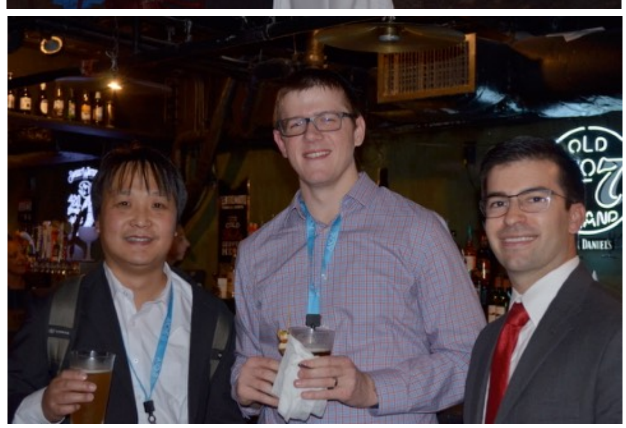

Dow Particle Processing
Recognition Award:
Dr. William Hendrickson
AVEKA Group
Sponsored by:
Dow


Sabic Young
Professional Award:
Dr. Christopher Boyce
Columbia University
Sponsored by:

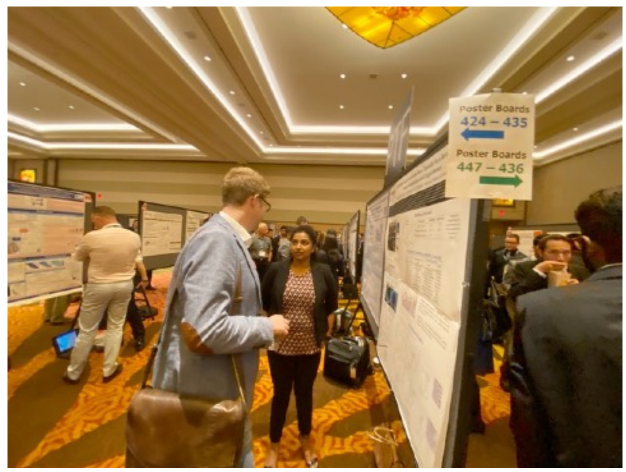

George Klinzing Best PhD Award:
Dr. Sarah Mena
University of Michigan
(PhD University of Florida)
Sponsored by:


Poster Awardees:
Julia Hartig
University of Colorado-Boulder
Keju An
Arizona State University


CPFD Travel Grant Awardees:
Gunda Harini
ITT Gandhinagar
Georgios Kelesidis
ETH Zurich
Koyel Sen
University of Connecticut
Kai Zheng
New Jersey Institute of Technology
Sponsored by:



Poster Session



Fellows' Breakfast

2019 AIChE PTF Awards

PTF Lifetime Achievement Award Sponsored by Elsevier

Flow Behavior of Cohesive and Aspherical Particles in Hoppers and Shear Cells

Jennifer Sinclair Curtis

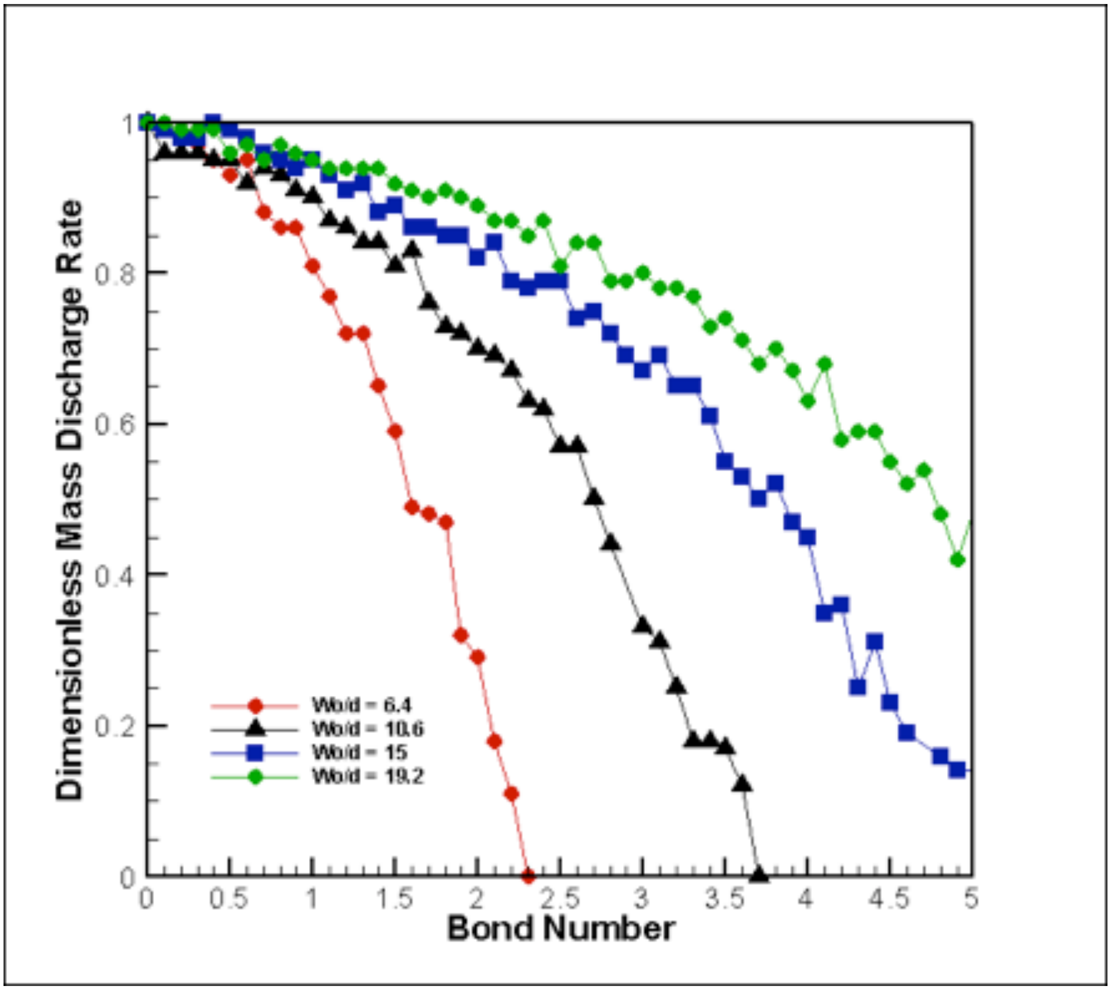
Distinguished Professor and Dean of College of Engineering, Chemical Engineering Department

University of California - Davis

Significant advances have been made in Discrete Element Method (DEM) simulations in their ability to describe the motion of cohesive and/or aspherical particles. In the Elsevier PTF Lifetime Achievement Award lecture at the 2019 Annual AIChE Annual Meeting, aspherical grains are described either as perfect cylinders or disks of varying aspect ratio or described using a linked and overlapping sphere approach. Using this linked approach, the flow of flexible aspherical particles can also be treated via a bonded particle model which incorporates normal and shear forces as well as bending and torsional moments. The bonded particle model also allows for breakage of aspherical particles during impact. In addition, in the talk and this summary, cohesion between particles is described as originating from surface moisture, described by a liquid bridge force model in the case of pendular liquid bridges. DEM simulations of wet, aspherical particles are validated via experiments of hopper discharge and measurements of particle-phase stress in a ring shear cell. Some example results include:

Hopper Discharge of Wet, Spherical Particles

DEM has been shown to be a powerful simulation tool to predict the flow behaviour of spherical particles in hoppers – both in wet and dry states ([1],[2],[3]). In the figure below, the predicted discharge of spherical particles from a hopper are shown as a function of hopper outlet width and Bond number (defined as the ratio of the cohesive force to the gravitational force acting on a particle). These DEM discharge rate predictions are validated via experimental measurements using cast iron and glass bead particles and silicone oil and water. The resulting Bond numbers of the various particle-liquid systems ranged from 0.3 to 3.5 [4]. For a given outlet width to particle diameter, the discharge rate decreases as the Bo number increases until the hopper becomes clogged and no mass is discharged. The 'dead area' near the hopper outlet increases with increasing cohesion due to the formation of particle clumps. In order to describe the resulting

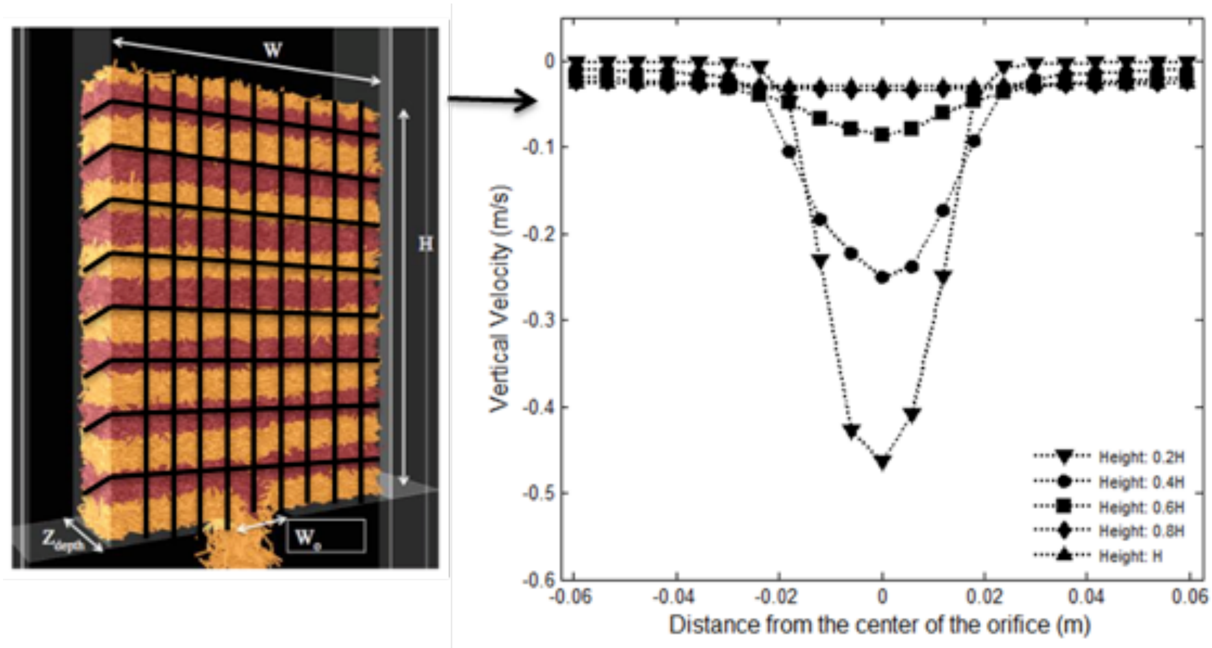


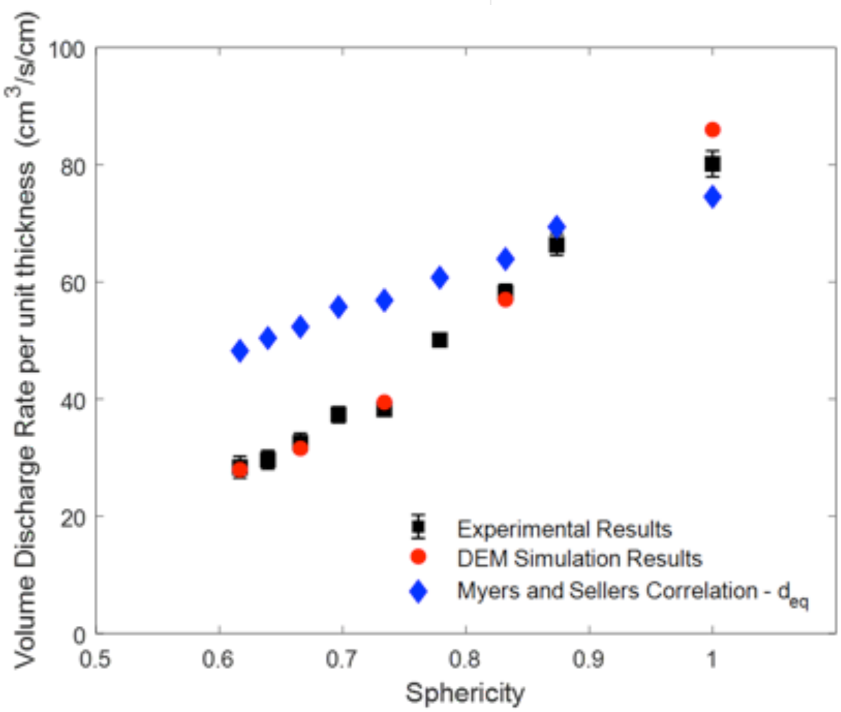
discharge rate, a simple modification of the Beverloo equation is proposed which incorporates the effect of the Bond number Bo:

$$W_{flat-bottom} = 1.03\rho_{flow} g^{1/2}[L_o - (1.9e^{0.39Bo})d][W_o - (1.9e^{0.39Bo})d]^{3/2}$$

Hopper Discharge of Dry, Aspherical Particles

Here, the discharge of non-spherical particles, specifically cylindrical particles, from a rectangular hopper is investigated. The behavior of both steel and plastic cylindrical particles with varying aspect ratio (same diameter, different lengths) is simulated via DEM and validated via corresponding experimental measurements. In the figure below, a representative grid in the DEM simulation (left) is employed to compute local particle velocities (funnel flow in this case) within the hopper (right). In addition, the effects of fill height, particle-particle friction, and hopper cone angle (90 and 55 degrees) are explored [5]. The cylindrical particles are simulated using the contact detection as outlined in [6].

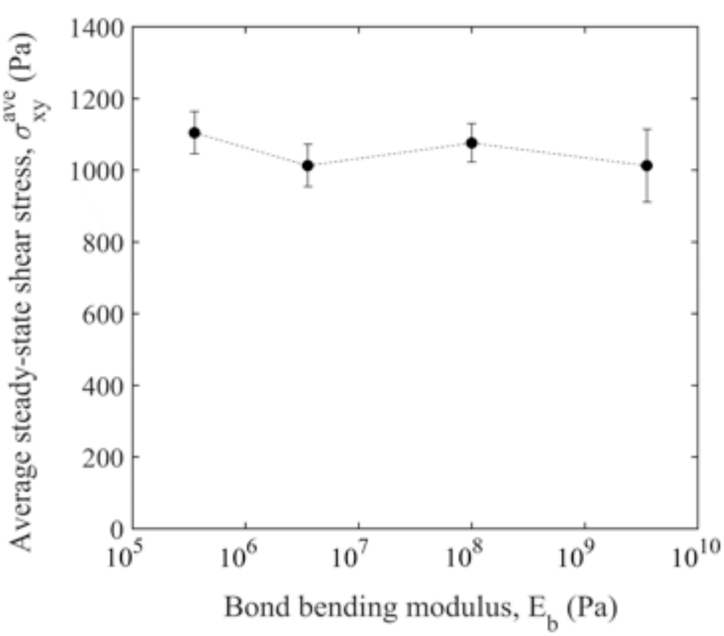


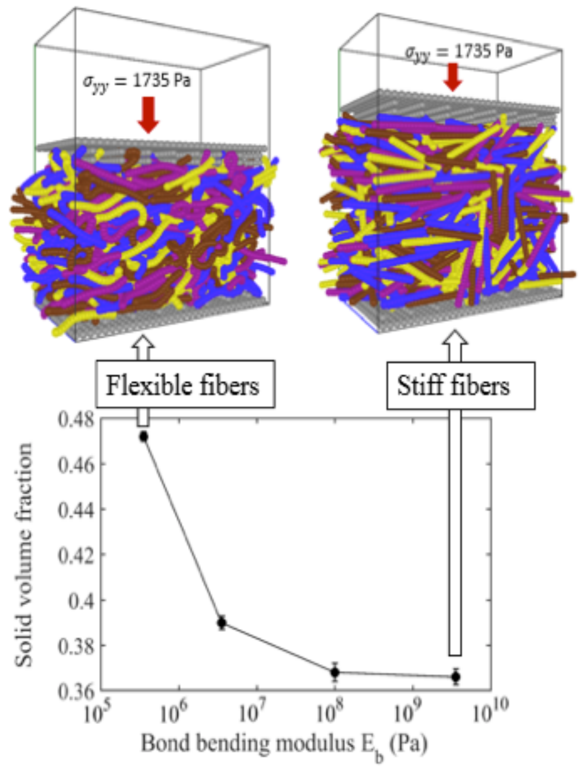


The DEM simulations show that the discharge rate of aspherical particles are drastically different from their spherical counterpart, with the discharge rate decreasing with increasing aspect ratio or decreasing sphericity. This trend is valid even taking into account the increase in equivalent diameter of the aspherical particle. This is shown in the figure below by comparing the discharge rate of spherical particles, based on the Myers and Sellers hopper discharge rate correlation, with the discharge rate of aspherical particles with the same equivalent volume diameter. Also, this figure shows that the DEM simulations are fully capable of predicting the discharge rate of the aspherical particles. The coefficient of friction also strongly affects the discharge rate – increasing friction significantly decreases the discharge rate. The critical value of friction coefficient in which the discharge becomes independent of friction is 0.1. The DEM simulations also show that discharge rate of cylindrical particles varies with the orifice width raised to the power 3/2, similar to the case with spherical particles. In addition, decreasing the hopper angle from 90 degree to 55 degrees decreases the discharge rate and further decreases in hopper angle increase the discharge rate. Based on a wide range of simulation and experimental data, a new hopper discharge rate correlation is proposed which incorporates the particle sphericity and longest particle dimension and is applicable to both spherical and aspherical particles [5].

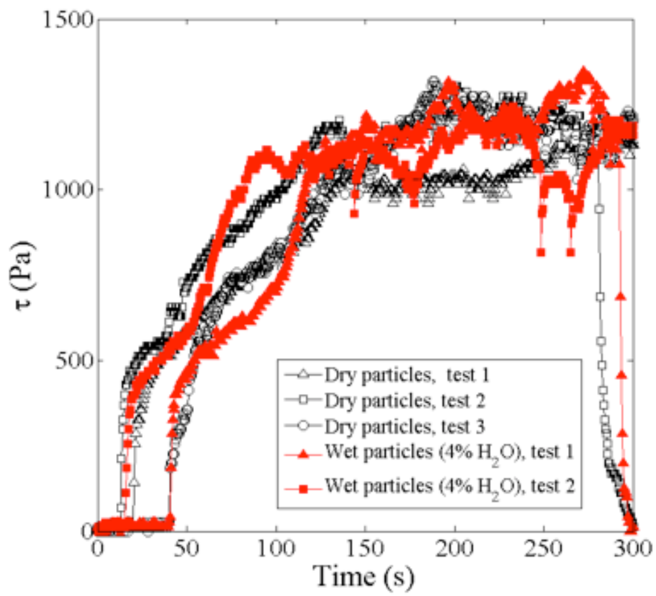
Shearing of Wet and Dry Flexible Particles

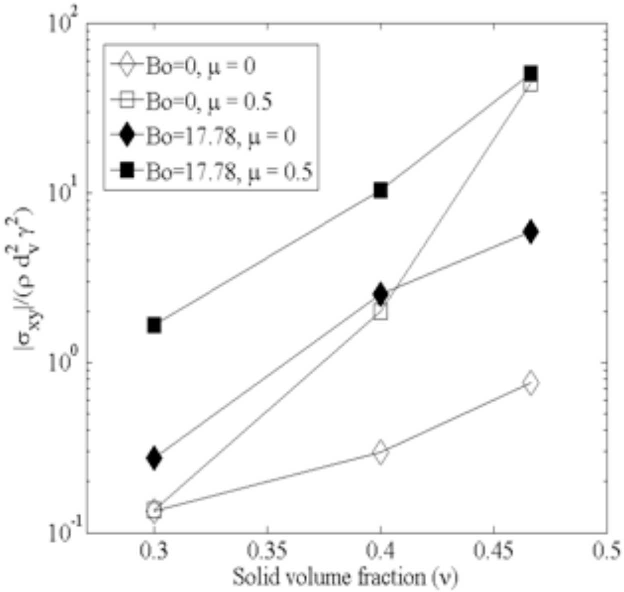
By describing a flexible elongated particle using many constituent spheres with a virtual bond between the spheres, the effect of fiber flexibility (the bond bending modulus) on its flowability is studied [7]. Both DEM predictions and experimental ring shear cell measurements (with dry rubber cord and dry fishing wire – both of aspect ratio 9) indicate that the shear stress is independent of particle flexibility (left figure below). This non-intuitive result is due to the fact that the solids packing in the shear cell at the same normal load is higher with the more flexible particles (shown in right figure below).





In addition, somewhat surprisingly, when surface moisture (4% water) is added to the fishing wire fibers, the resulting shear stress of the wet fishing wire particles is the same as the dry fishing wire particles. Although strong cohesive behaviour is observed when filling the shear cell with the wet fishing wire particles, DEM simulations also predict the same shear stress for the wet and dry fishing wire [8]. At low solids fractions, the effect of the particle cohesion due to the liquid bridge force does result in a larger shear stress for the wet fibers versus the dry fibers. However, at the higher solids fraction and with frictional μ=0.5 particles, as is present in the ring shear cell, the effect of particle shape dominates the flow behaviour, rather than the effect of particle cohesion. This is shown in experimental measurements (left) and DEM shear stress predictions (right) in the figures below.





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Lectureship Award Sponsored by PSRI

An Approach of Coupled KTGF of Granular Phase and DEM of Discrete Particles Applied to Gas-Solid Fluidized Beds

Lu Huilin

Professor, School of Energy Science and Engineering

Harbin Institute of Technology, China

1. Introduction

Fluidized beds are frequently used in industry for variety of processes, including heterogeneously catalyzed reactions, coal combustion and gasification. For the design, performance optimization and scale-up of gas-solid fluidized beds, a proper understanding of the complex flow hydrodynamics is important. Computational Fluid Dynamics (CFD) contributes significantly toward establishing a connection between numerical simulations and intrinsic processes, allowing for comprehensive explanations of overall gas-solid fluidization phenomena.

The models based on fundamental fluid dynamic equations can be classified into two broad categories, namely the Euler–Euler (EE) models and the Euler–Lagrangian (EL) models. In the EE model, averaged Navier–Stokes equations of mass and momentum conservations are solved in gas phase and granular phase. Closure laws based on the kinetic theory of granular flow (KTGF) (Gidasow, 1994; Fan et al., 1997; Sundaresan et al., 2018) are used to calculate granular phase stresses. The viscosity, pressure and energy dissipation of granular phase are calculated as a function of coefficient of restitution (CoR). As a result, this parameter works as an empirical tuning parameter, and its value affects the results significantly in KTGF-based EE simulations.

The EL model represents bed materials as a collection of discrete particles. The motion of discrete particle is solved by Newton's second law of motion using discrete element method (DEM) (Cundall et al., 1979; Zhu et al., 2008; Guo et al., 2015; Cocco et al., 2017). Hence, it can generate microscopic information including impacting velocity of individual particles. However, the effects of gas-particle velocity covariance are nearly negligible. This implies that the application of DEM-based EL models may require a model simultaneously taking the turbulent transport of granular phase into account.

The hydrodynamics of bed materials can be solved for the granular phase treated as continuum and conservation equations and the discrete particles solved by the Lagrangian formulation.

Coupling of the DEM-based EL and the KTGF-based EE means that the calculated results from collisions of discrete particles from DEM are used in KTGF of granular phase, and the gas turbulence and granular temperature from KTGF-based EE model is used in the calculation of motion of discrete particles in DEM. Thus, the KTGF-DEM-based EEL model is used in combination to overcome disadvantages inherent for EE and EL models and to improve the accuracy of fluidized bed modeling.

2. KTGF-DEM-based EEL model equations

The specific balance equations of gas phase are given by the general average balance equations of mass and momentum with the gas–particle drag force term as well as the gas phase turbulence model.

The basic equations of granular phase include the conservation laws mass and momentum with the gas–particle drag force term as well as granular temperature equation. The viscosity, pressure and energy dissipation rate are expressed as a function of CoR and granular temperature using KTGF.

The mathematical model of discrete particle movement consists of motion equations with the drag force term using DEM. The contact force is detected as a function of Poisson's ratio and elasticity moduli of discrete particles. The positions and velocities of discrete particles are determined at time intervals, and the impacting velocity is recorded during a contact of a pair of discrete particles.

2.1 Restitution coefficient of KTGF and DEM

Two formulation methods are used to calculate CoR. One is that the CoR is calculated from the impact velocity of a pair of colliding discrete particles according to its definition. The other one is that the CoR is determined from empirical correlations based on impacting velocity of discrete particles.

2.2 Drag forces of gas phase, granular phase and discrete particles

The interaction force between the gas phase and the granular phase is given by product of the interaction momentum transfer coefficient and relative velocity. The Huilin-Gidaspow drag model is used to determine *k*th cell momentum transfer coefficient in fluidized beds.

The drag force acting on a discrete particle depends on the relative velocity between a discrete particle velocity and surrounding gas velocity and the local momentum transfer coefficient of discrete particle *i* residing in *k*th cell. The value of local momentum transfer coefficient of the discrete particle is the *k*th cell momentum transfer coefficient divided by the number of discrete particles in the *k*th cell.

3. Bubbling bed simulations using KTGF-DEM-based EEL model

The instantaneous volume fractions and velocities are shown in Fig. 1 at the inlet gas velocity of 0.6 m/s in a 3D bubbling fluidized bed with the width and thickness of 44mm and 10mm. The density and diameter of particles are 1000 kg/m^3 and 1.2 mm. The initial granular volume fraction is 0.475 and the number of discrete particles is 9240 with the static bed height of 40 mm. The elastic modulus and Poisson ratio of discrete particles are 800×10^5 Pa and 0.33. The vectors show the variations of instantaneous velocities of discrete particles and gas phase, and the volume fraction contour represents granular phase in the bed. We see that the numerical simulations can reproduce the hydrodynamic characteristics of discrete particles, granular phase and the bubble motion of gas phase in the bed.

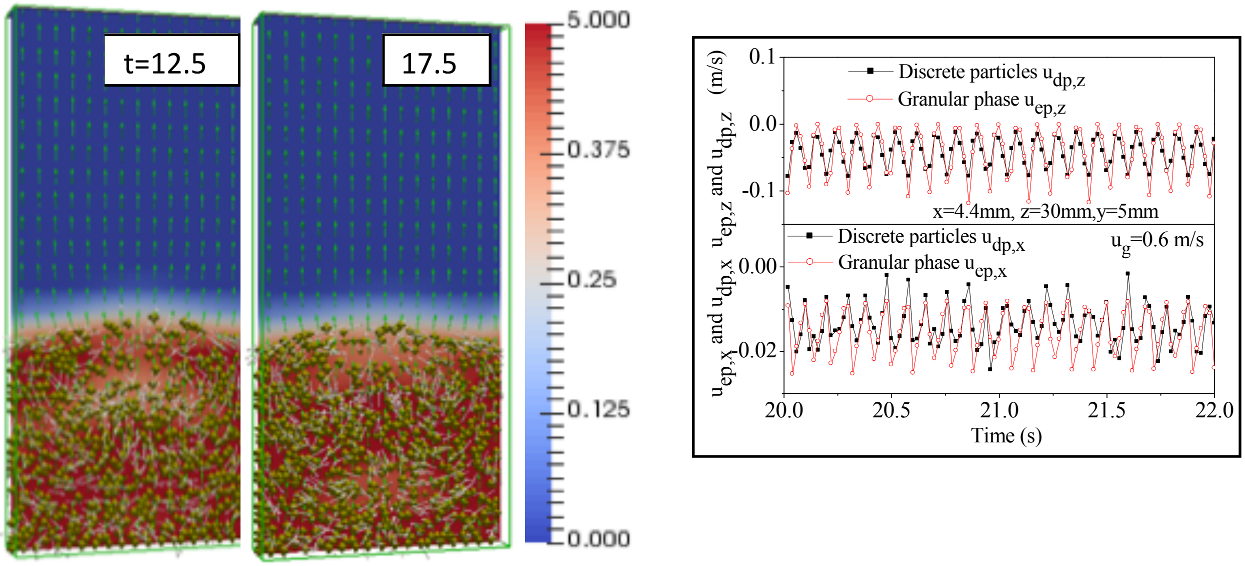

Fig. 1 Simulated instantaneous volume fractions and velocities (green color velocity vector for gas phase, white color velocity vector for discrete particles, volume fraction contour for granular phase)

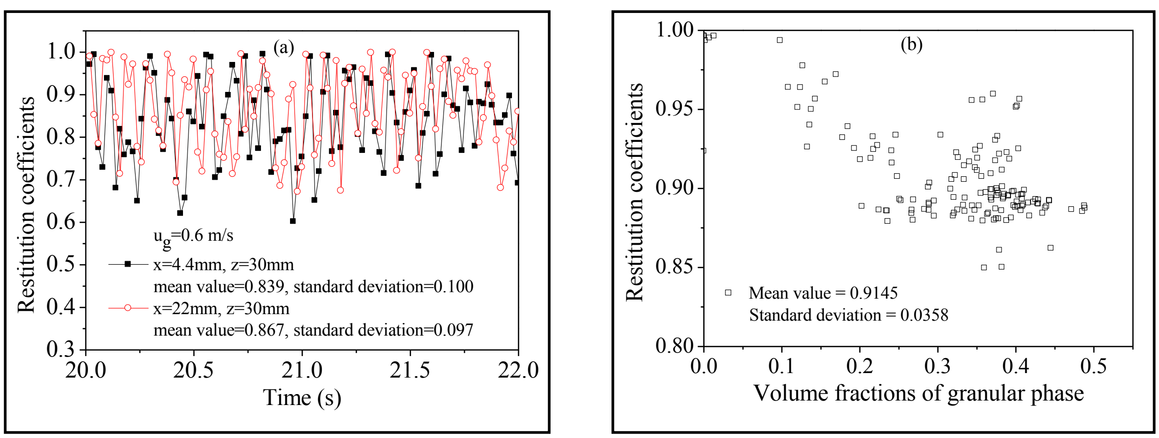

Fig. 2 Instantaneous and time-averaged coefficient of restitutions of granular phase

Simulated instantaneous vertical and lateral velocity components show that the trends of both velocity components are similar for discrete particles and granular phase. Fig. 2 shows the instantaneous and time-averaged CoR of granular phase. The fluctuating characteristics of CoR can be seen clearly, indicting the variation of impacting velocity of discrete particles. The time-averaged CoR decreases with increasing volume fraction of granular phase, and the high local volume fraction gives low CoR of granular phase because of the multiple collisions of discrete particles. The decrease of CoR causes the granular temperature to decrease. This in turn causes a decrease in the viscosity and diffusion of granular phase in the bed. The calculated mean value of CoR is 0.9145 in the bed.

4. Conclusions and suggestions

Using KTGF-DEM-based EEL model, the CoR used in KTGF is determined from the collisional interactions of discrete particles using DEM. The gas turbulence interacting with discrete particles used in DEM is determined as a function of granular temperature and gas-particle velocity covariance using TFM. It indicates that the description of hydrodynamics of fluidized gas and particles needs three momentum equations for granular phase, gas phase and discrete particles instead of two momentum equations for the granular phase and the gas phase in TFM models, and for the gas phase and Lagrangian discrete particles used CFD-DEM models.

For the further improvement of KTGF-DEM-based EEL model, the effect of rotation of discrete particles in the DEM can be taken in the calculations of rotational energy dissipations of the KTGF into account.

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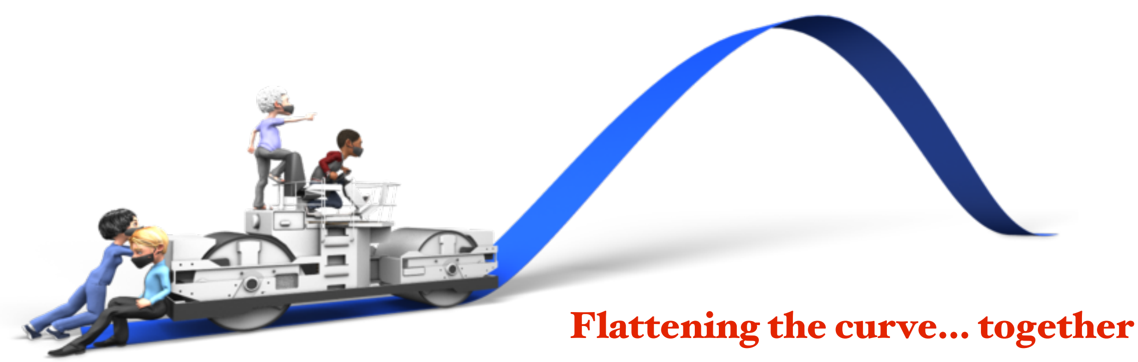

George Klinzing Best PhD Award Sponsored by University of Pittsburgh

Experimental Studies of Fluid-Solid Flows in Turbulent Dilute and Laminar Concentrated Regimes

Sarah Mena

Project Leader

Particulate Solid Research Inc. (PSRI, Chicago

Mixtures of liquid and solids are present in many engineering and geological processes such as hydraulic conveying, energy conversion, and the consolidation of soil sediments. Although they are widespread, the understanding of their behavior is not complete partly due to a lack of experimental data. These data are needed for the development of engineering models for a wide range of applications including optimization of industrial operations, reduction in energy demands, and prediction of undesirable processes like erosion, and underground instabilities. The objective of my Ph.D. work, under Prof. Jennifer Sinclair Curtis at the University of Florida was to better understand solid-liquid flows in two different configurations: turbulent dilute particle flows in pipes and dense particle flows in fluidized beds. The research was funded by the National Science Foundation (NSF) through the Partnerships for International Research and Education (PIRE) Center on Multiphase Flows and Technologies. A brief description of each project follows with the details found in journal articles.[1–3]

Solid-Liquid Turbulent Flows in Pipes

The scarceness of experimental two-phase flow data for turbulent flow in pipes has been identified as a roadblock for the progress of computational models that need detailed information for validation and model development[4]. In particular, there is a need for liquid-solid experimentation at Reynolds numbers above 30,000 at solids concentrations higher than 0.7% V/V. The present study starts to close this gap in knowledge by providing data for turbulent solid-liquid flow at conditions that have not been studied before.

Experimental setup and conditions

The liquid-solid turbulent flows were studied in a pilot-scale unit that could accommodate flows up to 490 GPM. The system operated in a loop, as seen in Figure 1. The velocity profiles were measured in a vertical section of the pipe located after 51 pipe diameters of undisturbed flow. The flow at the test section was confirmed to be fully developed and radially symmetric from the measured pressure drops and velocity profiles at different axial locations.

The experimental design matrix systematically varied six diameters of glass beads from 0.5 mm to 5 mm, concentrations up to 2% V/V, and Reynolds numbers from 200,000 to 350,000. Data for crushed glass, steel shot, and two sizes of stainless-steel cylinders were also collected. The results include the direct measurements of the three velocity components for the solid and the liquid phases, the measurements of the pressure drops, and the quantification of the solids concentration by direct sampling.

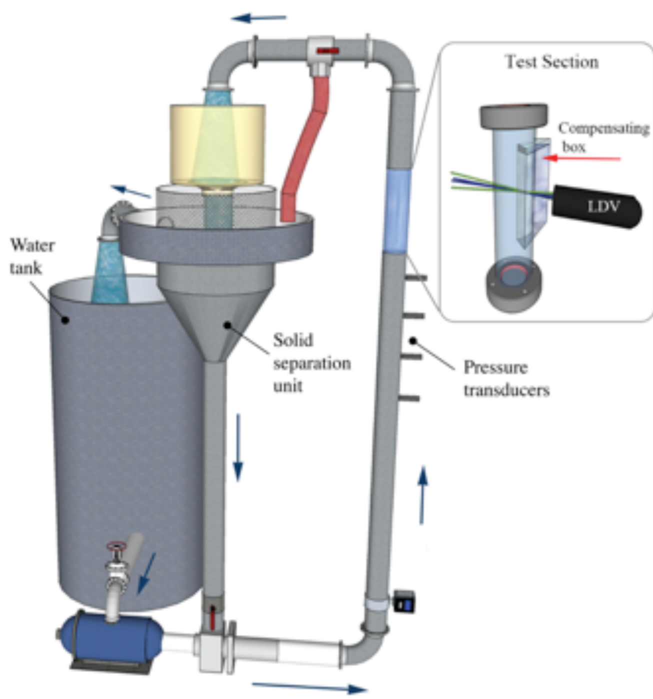

Fig. 1. Diagram of the pilot-scale flow setup. Arrows indicate the direction of the flow. The vertical test section where the velocity profiles are measured is located after 51 pipe diameters of undisturbed flow. Reprinted with permission.[1]

The challenge of measuring velocities in liquid-solid flows

The velocity profiles were measured using the non-intrusive optical techniques of Laser Doppler Velocimetry (LDV) and Phase Doppler Anemometry (PDA). One of the most challenging parts of solid-liquid flow experimentation involves how to differentiate the velocity of each of the phases accurately. The present study used a novel combination of intensity discrimination to distinguish the solid's signal and the size measurement of tracer particles to separate the liquid's hydrodynamic data. Mean and fluctuating velocities at different positions in the pipe were measured for the three velocity components resulting in detailed velocity profiles for each of the phases. The data allowed for the determination of the Reynolds stresses, the granular temperature, the kinetic energy, and the turbulence modulation calculations.

Highlights of the results from the velocity profiles

In general, the velocity profiles show augmentation of turbulence from the single-phase for all the conditions studied. The mean solid profiles exhibit slip and have a maximum velocity at the center of the pipe at the conditions tested. The velocity fluctuations for the solid and the liquid are reduced with increasing Reynolds numbers for all particle sizes and concentrations.

One of the most exciting results is observed in Figure 2, where the relative velocity decreases with increasing concentration for the Reynolds number of 200,000, but increases with increasing concentration at the Reynolds number of 350,000. An explanation for this change in trend comes from the steady-state momentum balance for the solid-phase seen in Equation 1:

$$(u_l - u_s)^2 = \frac{4}{3}\frac{d_p\,(1-\alpha_s)^{1.65}\,[\alpha_s \nabla P + \nabla P_s - \nabla \tau_s - \alpha_s \rho_s g]}{C_D \alpha_s \rho_f} \qquad (1)$$

where subscript "l" is for the fluid, and "s" is for the solid, is the solid volume fraction, is the fluid pressure, is the solid phase pressure, is the solid phase stress tensor, is the density, and is the drag coefficient. The drag coefficient increases with increasing concentration, and this can describe the behavior at the Reynolds number of 200,000. The behavior of the relative velocity at the Reynolds number 350,000 could be explained by the solid fluctuations shown in Figure 2b, which decrease with concentration. This reduction is caused by a decrease in the source of particle fluctuations from a flatter mean velocity (Figure 2a) and an increase in inelastic collisions. The solid fluctuations influence both the solid stress tensor, , and the solid pressure, , in Equation 1 and can increase the relative velocity with concentration.

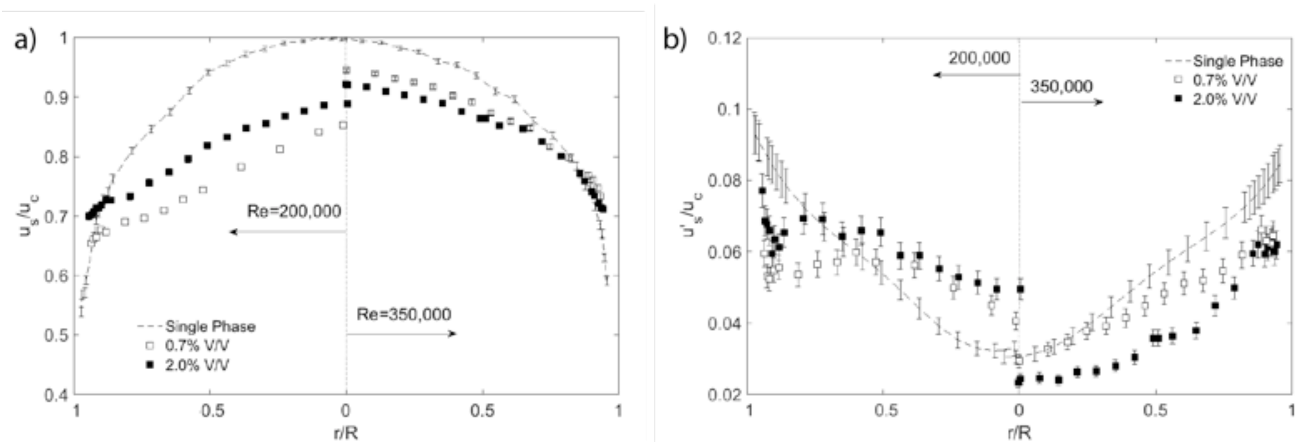

Fig. 2. Comparison of the effect of Reynolds number and concentration for a flow with 4 mm particles with the a) solid mean velocity, and b) solid axial fluctuations. Reprinted with permission.[1]

The behavior observed in Figure 2 hints at the complex relationship between the different variables in turbulent multiphase flows. The velocity profiles, pressure drops, and turbulent characteristics measured in the present study provide critical insight to aid in a better understanding of the physics involved.

Localized Fluidization in Liquid-Solid Flows

Localized fluidization is the type of fluidization where the injection of fluid is directed to a specific region of the bed, resulting in the mobilization of only a portion of the particle medium. Unlike traditional fluidization, there are very few experimental studies dealing with localized fluidization. Most of the previous investigations[5] focus on quasi-2D systems in shallow beds, where wall interactions may be significant. Furthermore, the majority of the earlier studies deal with steady-state beds where at velocities higher than the minimum fluidization limit.[5] Understanding how the fluidized region forms and develops is of importance for the operation of conical fluidized beds, the prediction of erosion on Earth's surface, and the safety of levees, dikes, and dams. This study provides quantitative information on the formation of localized fluidization and investigates how different parameters affect this process.

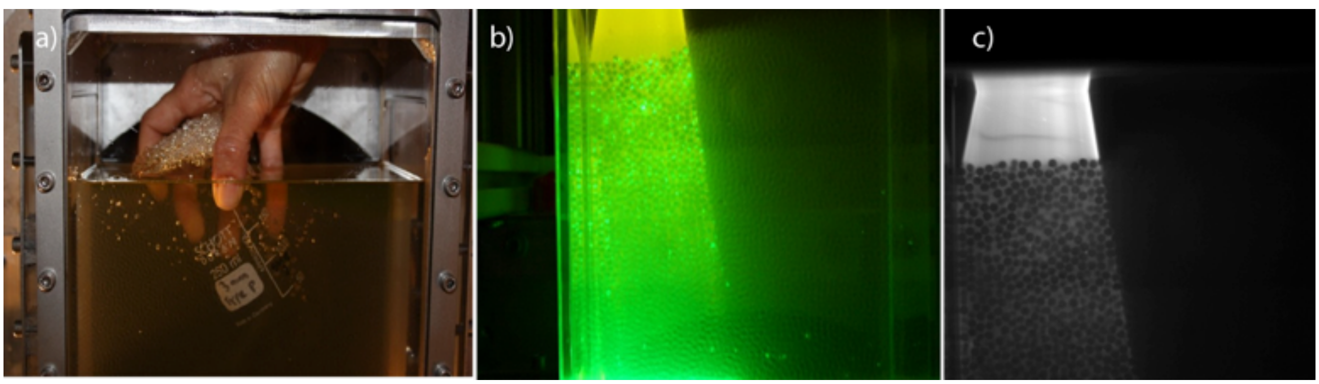

Fig. 3. Optical techniques used for localized fluidization studies with a) Refractive Index Matching (RIM) using a solid-liquid pair with the same index of refraction, b) a planar laser directed to the region of interest, and c) the resulting image collected by a camera with an optical high pass filter.

Observation of the fluidization in a particle bed

One of the challenges in the study of fluidization in a granular medium is the opacity of the bed. To overcome this limitation, a combination of Refractive Index Matching (RIM) and Planar Laser Induced Fluorescence (PLIF) were used in this study. RIM accomplishes a transparent bed by using a solid with the same refractive index as the liquid, as demonstrated in Figure 3a. The RIM system (glass beads-mixture of oils) was placed inside a plexiglass unit with dimensions of 30x20x10 cm. The injection port, the bed height, and the size of the particles could be varied systematically. The PLIF technique reveals a specific plane by directing a planar laser into the region of interest away from the walls, as shown in Figure 3b. The use of a fluorescent dye in the liquid and a high-pass optical filter results in images where the liquid is bright, and the particles are dark, as shown in Figure 3c.

Regimes of expansion

As shown in Figure 4, the formation of the fluidized region was observed. Initially, three regimes for the fluidized beds were established at increasing flow rates: static bed, cavity regime, and full fluidization. However, more detailed experiments showed that the cavity regime is an unstable state that grows into full fluidization if the flow is allowed to continue. These new findings allowed for the determination of two regimes for the expansion of the fluidization: a regular regime and an ultra-slow regime.

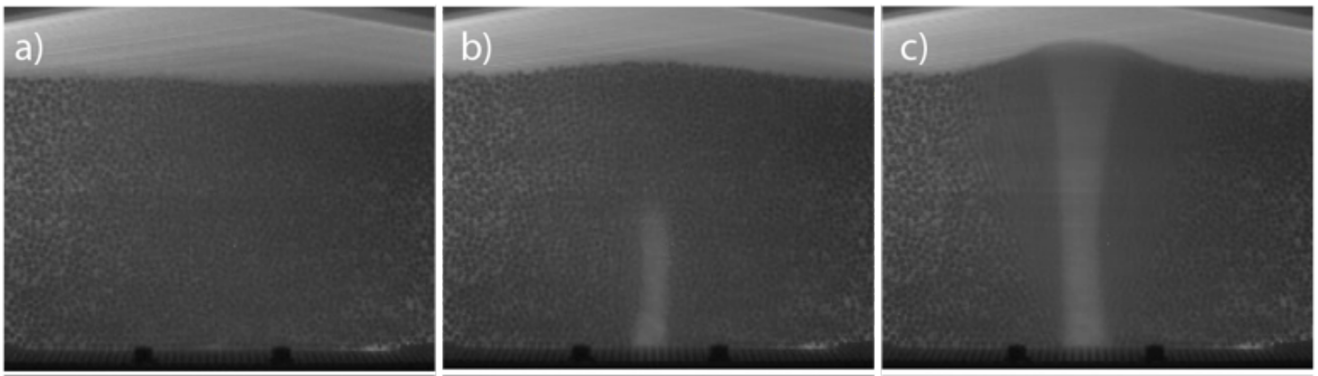

Fig. 4. Pictures showing the average of a video sequence for three different regimes for bed with 3 mm particles, an initial bed height of 100 mm. Reprinted with permission.[3]

Highlights of the results of the expansion regimes

The influence of the injection particle size, port diameter, and flow rate in the formation of the fluidized zone was studied. Some of the results for the latter two variables are presented in Figure 5. Figure 5a shows a plot of the rate at which the fluidized zone grows through time, where T_0 is the time that takes the fluidized zone to grow from the injection port to the top of the bed. The regular regime (open markers) presents an almost regular expansion, whereas the ultra-slow regime (closed markers) show a very small growth for most of the process except at the end where a fast expansion occurs. Figure 5b shows the rate of expansion as a function of time where it is clearer to observe that the ultra-slow regime expands up to three orders of magnitude slower than the regular regime. Furthermore, there is a marked influence of the size of the injection port on the rate of growth of the fluidized zone in the ultra-slow regime. Yet, almost no growth can be seen with the regular regime as compared using the injection port of 40 mm in diameter (green markers) or the injection port of 10 mm (black markers). These novel observations highlight the parameters that have the most substantial effect on the initial stages of fluidization. An analysis and a model are developed in the paper.[2]

Path Forward

The projects presented explore solid-liquid mixtures in two distinct configurations. Future directions for the turbulent pipe studies should include experimentation at higher concentrations that are of importance for many industrial applications where flows routinely have solid volume fractions around 0.3-0.5. These new investigations require a much-needed development of measuring techniques that can operate at high solids content. Meanwhile, the fluidized studies could explore the effects of cohesive and polydisperse granular mediums that could better represent some of the real-life geological and industrial applications.

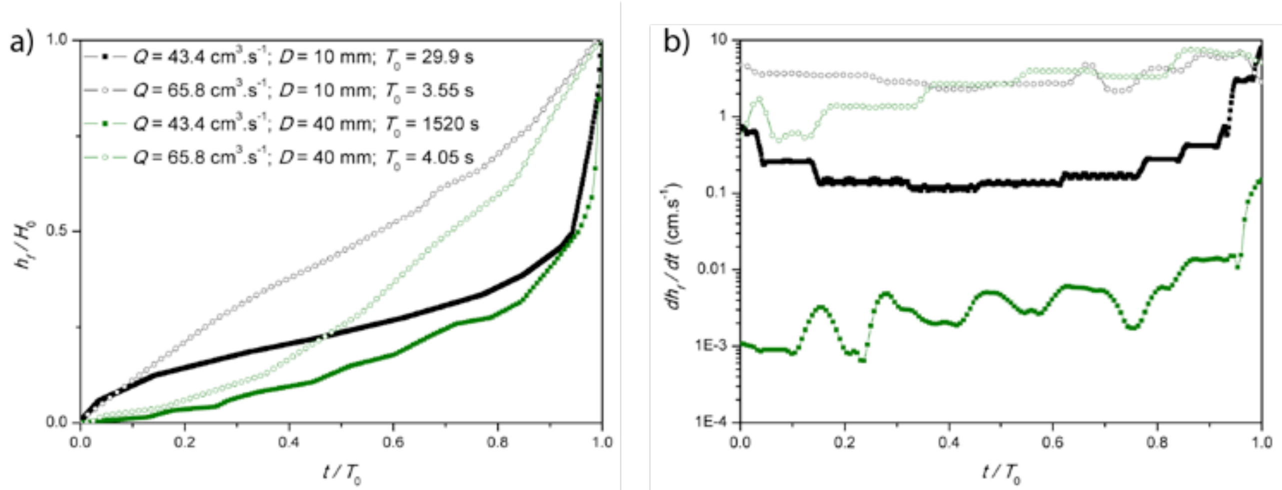

Fig. 5. Expansion of the fluidized zone in a bed of 3 mm particles with an initial height of 125 mm in the regular (circle markers) and ultra-slow (square markers) regimes of expansion. Data from experiments with an injection port of 10 mm are in black and the ones with an injection port of 40 mm are in green with respect to a) the height of the fluidized zone (h_f) normalized by the initial bed height (H_0) as a function of time, and b) the rate of expansion as a function of time. Reprinted with permission.[2]

After finishing my academic training, I am thrilled to continue exploring the fluid-particle interactions in my new job at Particulate Solid Research Inc. (PSRI). PSRI conducts research in all areas of particle technology with careful consideration of the scale of the systems and the particle properties. I am excited to join their quest to understand the complex and consequential world of particles.

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The Executive Committee strongly encourages nominations from all qualified applicants for each award, especially nominees who are women and/or otherwise underrepresented backgrounds in our Forum, the Institute, and in STEM fields.

Key information for this year is below.

- **The Nomination process is a single step.** The full package is due by **Friday, May 29th, 2020**, containing items specifi c to each award.
  - If the nominee has previously received any award from PTF, an explicit statement of new accomplishments or work over and above those cited for the earlier award(s) must be included (maximum of 1 double spaced page).
  - Selected bibliography (including major papers published, books, and patents)
- **It is required that the nominators are current PTF members**
  - For the PTF Lifetime Achievement Award, one of the support letters must be from a former PTF Lifetime Achievement Award winner.
- **Nominees are not required to be PTF members**
  - Except for the PTF Service Award, the Executive Committee has released the nominee PTF membership requirement. PTF membership is still expected for the PTF Service Award.
  - In a given year, the same person cannot win more than one PTF award
  - Those making nominations must be members of AIChE-PTF at the time of the nomination.
  - Wait period for nomination after previous award

- A former PTF award winner cannot be nominated for another award for at least three years after receiving any previous PTF award

All questions and concerns should be addressed to me by email to gilchrist@lehigh.edu with the subject line including the name of the award. The Executive Committee is actively developing processes to ensure equity, diversity, and inclusion in the forum and its awards.

- James Gilchrist

PTF Vice Chair 2018-2020

Call for Nominations for AIChE Particle Technology Forum Executive Committee Elections

The AIChE Particle Technology Forum (PTF) Executive Committee, according to the AIChE PTF by-laws, has equal representation between academics and individuals working in industry and other sectors that interface with the field of particle technology. The Executive Committee members act as liaisons to the PTF and play an important role in improving PTF by discussing and voting on PTF policy, working on PTF Events (such as judging posters at the annual meetings), recruiting new members/officers, and helping with PTF standing committees.

We are soliciting nominees for two (2) open positions as Academic Member Representative to the PTF Executive Committee and two (2) open positions for the Industrial Member Representative to the PTF Executive Committee. Interested candidates must be members of AIChE and the AIChE PTF, be willing to commit to a four (4) year term beginning in 2021, and lastly provide a short (one paragraph) biography for the ballot, which will be released as part of the upcoming summer newsletter. This year's election will be held between August 31, 2020 and October 20, 2020.

Interested individuals should reach out to michael.molnar@dow.com. Deadline for nominations is **June 1, 2020.**

- Michael Molnar, The Dow Chemical Co.

Executive Committee - Industrial Member Representative

PTF Membership

To continue receiving the PTF newsletters (3 issues per year) and stay current with particle technology events and news, please make sure to renew/ start your membership by either:

- Checking Particle Technology Forum when renewing your AIChE membership annually,
- Becoming a PTF lifetime member so that you don't have to renew membership every year

Become a PTF only member

(Annually $15, Lifetime $150)

If you don't see the PT membership in your renewal screen, you can choose "Update Membership Options" and add PTF to your order.

You can also contact AIChE customer service at 800-242-4363 (US);

203-702-7660 (Outside the US); or email customerservice@aiche.org

for membership questions and help.

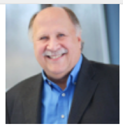
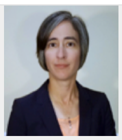
- PTF Membership Committee

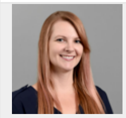
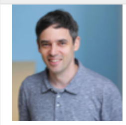
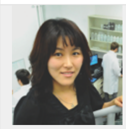
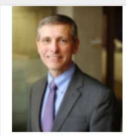
Particle Technology Forum Organization

Officers

Chair Dr. Bruce Hook bdhook@dow.com	
Co-Chair Dr. Jim Gilchrist gilchrist@lehigh.edu	
Treasurer Dr. Benjamin Glasser bglasser@rutgers.edu	
Past Chair Dr. Raj Dave dave@njit.edu	

✦ *Executive Committee*

Industry	
Michael Molnar michael.molnar@dow.com	
Willie Hendrickson whendrickson@aveka.com	
Dr. Brenda Remy brenda.remy@bms.com	
Dr. Mayank Kashyap mkashyap@sabic.com	

Academic	
Dr. Heather Emady heather.emady@asu.edu	
Dr. Aaron Moment ajm2293@columbia.edu	
Dr. Ah-Hyung Alissa Park ap2622@columbia.edu	
Dr. Richard Lueptow r-lueptow@northwestern.edu	

✦ *Liaisons and Committee Chairs*

CTOC Liaison	Dr. Reza Mostofi	reza.mostofi@honeywell.com
Nominating Committee Chair	Dr. Michael Molnar	michael.molnar@dow.com
PTF Newsletter Committee Chair	Dr. Mayank Kashyap	mkashyap@sabic.com
PTF Webmaster	Dr. Madhusudhan Kodam	madhusudhan.kodam@corteva.com
PTF Student Workshop Chair	Dr. Mayank Kashyap	mkashyap@sabic.com
PTF Programming Chair	Dr. Ben Freireich	ben.freireich@psri.org
PTF Dinner Sponsorship	Dr. Jim Gilchrist	gilchrist@lehigh.edu
PTF Awards Sponsorship	Dr. Reddy Karri	reddy.karri@psri.org
PTF Education Committee Chair	Dr. Shrikant Dhodapkar	sdhodapkar@dow.com
FPST 2020 Chair	Dr. Heather Emady	heather.emady@asu.edu
Staff Liaison	Ms. Darlene Schuster	darls@aiche.org
	Ms. Diane Cappiella	dianc@aiche.org
Accounting	Ms. Leila Mendoza	leilm@aiche.org

✦ *Programming Leadership*

Group 3A: Particle Production and Characterization	**Group 3D: Nanoparticles**
Chair: Dr. Bryan Ennis bryan.ennis@powdernotes.com	Chair: Dr. Timothy Brenza timothy.brenza@sdsmt.edu
Group 3B: Fluidization and Fluid-Particle Systems	**Group 3E: Energetics**
Chair: Dr. Jia Wei Chew JChew@ntu.edu.sg	Chair: Dr. Travis Sippel tsippel@iastate.edu
Group 3C: Solids Flow, Handling and Processing	
Chair: Dr. Rich Lueptow r-lueptow@northwestern.edu