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Electrohydrodynamic instability using linear stability analysis

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Charges and electric field are known to modify the existing instabilities and hence would result in an altogether distinct instability in the fluid mechanical system. It is due to the coupling between electrostatics and fluid flow which gives rise to what is called the electrohydrodynamic effect. The Electrohydrodynamic transport phenomenon is fundamental to a variety of engineering applications such as electrokinetic reactions, electrosprays, electrostatic printing, mixing phenomenon as well as in biological systems involving lipids and proteins which have charged surfaces. On one hand, an unstable system is desirable in certain applications like mixing whereas applications like ionization would desire the system to be stable. In this article, we aim to show the effect of presence of a charged interface on the stability criterion of a system of two immiscible planar layers of liquid as shown in Figure 1. We intend to calculate a stability criterion for both a constant potential and a constant charge density boundary conditions.

The stability of a flat charged interface between two immiscible liquids is studied using linear stability analysis. Surface charges may be present at the interface due to insoluble surfactants or adsorption of ions. Presence of these charged species greatly affects the base state as well as the stability of the interface due to its presence as a boundary condition. The set of electrostatic and hydrodynamic differential equations are solved to calculate the perturbed velocity, potential and pressure variables and primarily the critical values of interface properties that would destabilize the interface [1- 3].

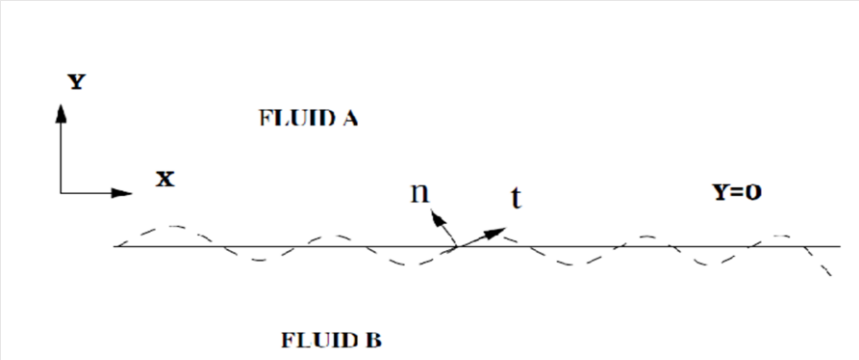

Figure 1: Schematic diagram showing the coordinate system and the configurations

Generalized study has been done for a system of two electrolytes with varying hydro-dynamic and electrostatic properties for constant charge and constant potential boundary conditions. For system at low potential $\emptyset < \frac{k_B T}{e}$, where Debye-Huckel is applicable, there occurs a critical value of surface tension (σ, non-dimensionalized $\frac{\tau_s^2}{\epsilon_A \kappa_A}$) to surface charge density(τ_s) ratio which lead to destabilization. At critical surface tension, growth rate becomes just stable $\forall k$, and for all $\sigma < \sigma_{crit}$, it is always unstable and $\sigma > \sigma_{crit}$, it is stable. The critical σ is shown in Figure 2 for varying values of $\varepsilon_r k_r$, where ε_r and k_r are the ratio of dielectric constant and inverse Debye length of liquid B to A respectively. For all non-dimensional σ values greater than the shaded region, the system is stable. From the curve, it is prominent that with increase in k_r values critical σ value decreases, i.e. more surface charge density and less surface

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tension is required to stabilize the system. Interestingly, upon converting the surface charge and potential for the two boundary conditions in terms of each other, the critical ratio of surface tension to charge was shown to be equivalent for both. Variation of charge density parallel to the surface is neglected here.

Upon perturbation of the interface, there may be redistribution of charged ions on the interface. This leads to change in the surface charge density. Thus we also focused on the effect of surface diffusivity. In planar geometry D_s (Nondimensionalized surface charge diffusivity Coefficient) had no effect on the s - k curves.

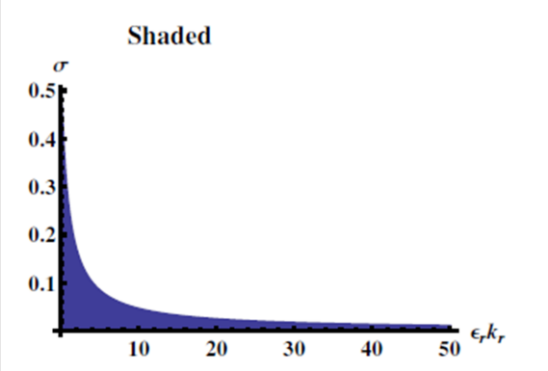

Figure 2: Plot of critical non-dimensional σ and $\epsilon_r k_r$

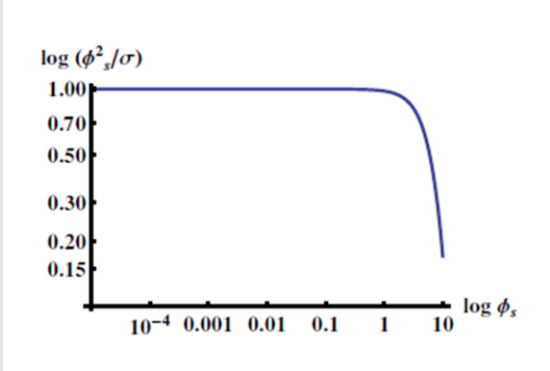

Figure 3: Log-Log Plot of $\emptyset_s^2/\sigma$ - vs $\emptyset_s$ and $k_r = 1.0$ $\epsilon_r = 1.0$

For higher values of potential $\emptyset > \frac{k_B T}{e}$, non-linear Poisson-Boltzmann model is more accurate. We studied the problem in a constant interface potential Ψ_s framework. The interface charge(τ_s) and potential(Ψ_s) can be related to each other using net accumulated charge balance(normal) at the interface, and the constant potential boundary condition at the interface. The critical non-dimensional surface tension σ^* for this system is as follows:

$$\frac{\sigma^*}{\epsilon_A \mathrm{K}_A \left(\frac{k_B T}{e}\right)^2} = \frac{8\tanh^2\left(\frac{\Psi_s e}{4k_B T}\right)(1 + \mathrm{K}_r \epsilon_r)}{1 - \tanh^2\left(\frac{\Psi_s e}{4k_B T}\right)} \quad (1)$$

For the Debye-Huckel approximation, the non-dimensional critical surface tension σ* is given as:

$$\frac{\sigma^*}{\epsilon_A \mathrm{K}_A \Psi_s^2} = 0.50(1 + \mathrm{K}_r \epsilon_r) \quad (2)$$

The surface tension $\sigma^*$is non-dimensionalised by $\epsilon_A \mathrm{K}_A \left(\frac{k_B T}{e}\right)^2$and the interface potential Ψ_s is non-dimensionalised by $\frac{k_B T}{e}$ and is denoted by $\emptyset_s$. For a constant value of $\mathrm{K}_r \epsilon_r$, the critical surface tension for Debye Huckel system is constant. For the Poisson's equation, at lower values of $\emptyset_s$, the criteria matches Debye Huckel, however at higher values of $\emptyset_s$, the critical value of $\emptyset_s/\sigma$ decreases. The plot of critical ratios are shown in Figure 3. Thus, with Debye Huckel approximation, the stability criterion is overestimated [1].

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The changing phase of the Automotive Industry

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The global automotive industry is going through a paradigm shift where the conventional IC engines will be slowly but surely replaced by electric drivetrains. The total global automotive sales including passenger cars and commercial vehicles in the year 2017 was greater than 97 million units which is a 66% increase over the year 2000 and almost 33% increase over a decade in the year 2007 when the global automotive sales were registered at 58 million units and 73 million units respectively. Norway already has a 33.5% market share of electric vehicles by the year 2016 and Netherlands has already announced that by year 2035, they are phasing out vehicles with internal combustion engines. The electric vehicle market share is continuously on the rise in other European countries like France and UK, United Nations and in China.

With the ever-growing automotive market, decreasing fossil fuel reserves and rapidly changing climatic conditions, there is a pressing need for switching to sustainable transportation. More and more major global automakers are investing hugely in the technologies for hybridization / electrification of their portfolio products and the Indian auto industry is also following suit. This is an essential step towards meeting the stringent emission norms and providing better fuel efficiency. Owing to the urgency of the need, hybridization and electrification is also imposed and backed by government policies of various nations in the form of incentives, subsidies and tax benefits offered both to the OEMs and customers on selling and purchase of hybrid and/or electric vehicles. In India as well, the Department of Heavy Industries (DHI) has formulated FAME India, a policy for the faster adoption and Manufacturing of Hybrid and Electric Vehicles in India.

The range of hybrid vehicles includes the mild hybrids, strong hybrids and plug-in hybrids in the order of increase in the degree of hybridization. Apart from the conventional IC engine, the hybrid vehicles are powered by a more efficient battery pack and a motor-generator. These vehicles have a set of basic hybrid functions like start-stop (where the engine is turned off during start-stop situations in signals or traffic jams on clutch disengagement and is turned on again on clutch actuation), passive assist (wherein rather than the engine, the battery pack provides power to the electrical loads of the vehicle like the head lamps, horn, infotainment system etc.), active assist (where the motor assists the engine during the high-power demands during acceleration) and recuperation (where the braking energy is used for charging the battery pack). Additionally, the strong hybrids and the plug-in hybrids provide pure electric drive up to a range of 10-15kms and 60-70kms respectively. These hybrid functions save significant amount of fuel and harnesses the braking energy which is wasted as heat in conventional vehicles thereby providing better fuel economy. Hybridization also reduces the CO_2 emission tremendously depending upon the degree of hybridization. Electric vehicles on the other hand are entirely propelled by the electric motor powered by a battery pack. It produces zero emission and can provide up to 200-300kms of electric range in a single charge.

The increase in hybridization / electrification has in turn spurn a significant growth in the research and development of the advanced energy storage solutions worldwide. This includes electrochemical solutions like batteries, fuel cells, ultra-capacitors, etc. wherein the chemical engineers and material technologies have become prime contributors towards developing the future of automotive propulsion systems.

The energy storage solutions used for automotive applications must meet the various design challenges like high energy and/or power demands based on the specific application, stringent weight and volume targets to meet the component packing boundaries, desired target life at extreme usage and temperature conditions, faster charging and high levels of safety and crash regulatory standards. This requires development of novel energy storage technologies with high specific energy and power density which uses chemistries that are stable and safe in the entire automotive operating range. The current hybrid and electric vehicles uses the more efficient lithium-ion battery rather than the conventional lead-acid battery. Lithium-ion batteries have higher specific energy (Wh/kg), are more compact, light-weight, has greater charge acceptance and wide operating window in terms of the battery state of charge. This additionally helps get away with the lead based chemistries and reducing the lead footprint.

On the flip side, lithium batteries have very less abuse tolerance. Additionally, the demand to increase the range of the hybrid/electric vehicles has led the researchers to investigate newer battery chemistries. Solid state chemistries, metal-air and lithium-sulphur batteries are some of potential candidates for the next generation electrochemical sources. These technologies are however not mature yet and probably are almost a decade away from commercialization.

Though various initiatives are being taken at multiple level, it is difficult to estimate when the entire automotive industry will be completely electrified. Apart from being technology ready, it requires huge investments in infrastructure for building charging station, battery swapping facilities, after market support to name a few. Though India envision to reach there by 2030; according to experts it will need at least 40 to 50 more years. And until then hybrid and plug-in hybrids will continue to be the middle ground.

Multiphase reactor design – an outlook

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Over 99% of the chemical process in industries are multiphase in nature, spanning across chemicals, petrochemicals, pharmaceuticals, bioprocess, environmental remediation, energy industries. Some of the widely used multiphase reactors are gas – solid (e.g. circulating fluidized bed), liquid – solid (e.g. fluidized beds), gas-liquid-solid (e.g. slurry bubble column), gas – liquid (e.g. bubble columns). Even though the capital investment of these reactors is 5-15% of the plant, their performance decides pre and post reactor unit processes, thereby profitability of the entire plant (Duduvokic, 2010). Further, the performance of these reactors decides the yield and selectivity.

The performance of the reactor is mainly a function of inputs (reactants), kinetics and contacting. If the contacting (transport) is well defined, quantification of performance is relatively easy. Ideal reactors are one such systems where the transport is well defined. However, real reactors are rarely close to ideal. In the case of single phase systems, non-ideal reactors can be approximated with the residence time distribution (RTD), which is sufficient to give the reliable and dependable results in most of the cases. However for the multiphase reactors, RTD is not enough, as the phase distribution are critical to quantify the reaction, and hence the yield. Further, multiphase flows are multiscale and unsteady in nature, thus adds more complexity to its design. To understand the complexities of multiphase reactors, consider the gas – solid circulating fluidized bed where the solids is porous catalyst and gas is reactant and flows co-currently upwards. For the reaction to proceed at the required rate, gas has to come in contact with the active sites of catalyst for sufficient time. To reach active sites, gas has to diffuse through the pores from the surface of the catalyst. This depends on the distribution and velocity of the catalyst and gas phase in the reactor. Further, solids forms a meta stable structures called clusters (of short life time), which reduces the contact between the gas and solids. Thus, multiscale phenomena viz., molecular (reaction), micro (particle), meso (clusters, eddies) and macro (distribution, velocities) occurs in the reactor. ***Ultimately, it is required to quantify inter and intra phase transport on single catalyst particle scale and single turbulent eddy, phase distribution/ contacting, exchange rates, flow pattern on the reactor scale and intrinsic kinetic rates.*** Such quantification enables the design and comparison of reactors based on yield, selectivity, productivity, energy consumption/efficiency and environmental impact.

Currently, most of the process industries, do design based on their prior experience with well-known reactors. Process chemistries in the lab is found by trial and error. The best process obtained will be tested in the bench scale with well-known reactor and best operating conditions will be obtained by statistical approaches. Then the new process is tested on the pilot plants. Scale-up will be done based on the *empirical equations* mostly developed in 1950's and plants are built largely relying on the experience of contractors. Such developed systems will have start-up problems and largely the reactors perform poorly and whole plant will run on experimental basis for the entire lifetime (Duduvokic, 2010). This apathy is result of the usage of empirical equations due to the lack of understanding of multiscale kinetic interactions and variation of these interactions with the scale. Risk of commercialization is directly proportional to the level of understanding of these multiscale phenomena.

Multiphase reactor design entirely on the theoretical basis (from molecular scale to reactor scale) which accounts all the phenomena would be ideal solution to reduce the risk of commercialization. Direct numerical simulation (DNS) coupled with the kinetics is one such technique which can account all

the known phenomena happening in the reactors. In DNS simulations, Navier Stokes equations are solved without any approximate models (like averaged turbulent models) in a spatial grid, which is of order of scale smaller than the Komologrov scale. However it is impossible to use DNS even for the bench scale system due to the huge computational power requirement. For instance, simulation of separated *single phase turbulent flow* will require 10^{16} grids and hardware to solve such a requirement may expected to available by the year 2080. Hence, using DNS for the design is elusive in the near future.

Computational fluid dynamics (CFD) coupled with reaction kinetics is a practically viable option in the near future. Euler – Euler and Euler – Lagrangian models are the two widely used CFD approaches for the multiphase modeling where kinetics is included as a source term. In Euler – Euler (EE) model, phases are considered as interpenetrating continua irrespective of the nature of phases (fluid or solid). Euler – Lagrangian (EL) models preserve identity of the phases. Since they trace each individual discrete phase (solids or bubbles) as a separate entity leading to the requirement of high computational power compared with the EE. However, both of these models requires closures for inter and intra phase interactions (e.g. drag, lift, virtual mass, solid – solid interaction), turbulence, heat and mass transfer, diffusivities, phase change, etc. These closures are largely based on empirical equations which are mostly developed from the experiments. Typically simulations are tuned to match the experimental data. Such a tuned model do not give the intended results at different scales, effectively undermining the need of the model.

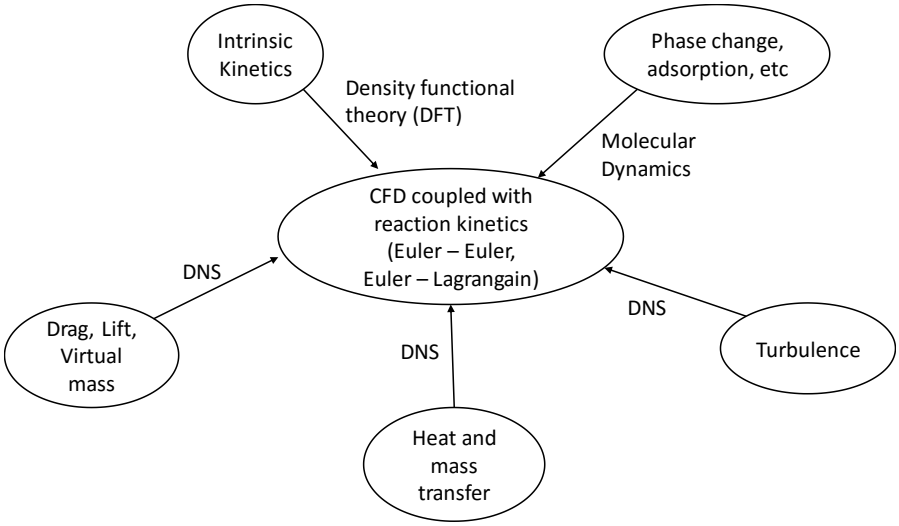

Figure 1. Schematic of the multiscale high fidelity model

To address this, multiscale modeling is widely considered as the way out. In this approach closure for the higher scale model (reactor scale) is developed using the intensive modeling approaches (like DNS). Such developed closures is validated with the experiments and then integrated to the higher scale (reactor scale) model. This approach gives more reliable and sufficient model for all the practical purposes of the design and scale-up (van der Hoef et al. 2006, Joshi and Nandhakumar, 2015)). Figure 1 shows schematic diagram of one such multiscale approach. Most of the transport closures were developed based on the highly sophisticated DNS. Kinetics can be modeled using highly sophisticated density functional theory (DFT). However, DFT have many challenges, at this stage it cannot be applied to multistep reactions involving multiple elementary molecules. An alternative approach is lumped kinetic equations developed based on the thermophysical properties and intermediate molecules rather than based on

electron cloud interactions as in DFT. Chemkin software gives such a capability. Phase change and other physical processes like adsorption can be modeled using molecular dynamics (MD) simulation. It is to be noted here that these highly sophisticated models are used to get insights which is usually not possible through the experiments. Even though this framework is very promising, there are lot of work need to be done. Infact, none of these highly sophisticated models are studied widely due to the computational challenges and mathematical difficulties. Interested readers can refer excellent review of DNS in multiphase systems by Deen et al. (2014) to understand the difficulties and challenges associated with it. In addition to that, integration of developed models to the higher scale models or upscaling of these information from the detailed models as closure to the higher scale models is an another challenge which is least understood. Mathey (2009) demonstrated one approach where upscaling of heat transfer is addressed. Validation of these models is another important challenge to be addressed. Thanks to the development of high fidelity experiments like radioactive particle tracking (RPT), Laser Doppler Anemometry (LDA), high speed particle image velocimetry (PIV), computational tomography (CT), Ultra-fast x-ray tomography. These techniques give the capability to validate at the macroscale using mean and turbulent quantities. However, microscale validation are still limited. For example, there are only approximate ways to validate the drag, lift and virtual mass through experiments.

To conclude, future design and scale-up of reactors based on more fundamental approach will give more predictable and controllable multiphase reactors. Multiscale approach is the promising one, where different high fidelity models validated at each scale is integrated to the reactor scale models. However, to achieve these, lot of work has to be done, like model development using higher fidelity techniques, upscaling of these information to the reactor scale models and development of tools or methods for validation.

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Computational Intelligence Techniques and its Application to Chemical Engineering Problems

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Optimization, in its simplest sense is to determine decisions so as to utilize the available resources in the best possible way. The classical optimization techniques, often known as mathematical programming techniques, are efficient enough to solve special category of problems. Many of these techniques rely on the gradient information and are inherently not suitable for black-box optimization problems. Moreover these techniques rely on repeated solution of a single objective optimization problem to determine the trade-off solutions (Pareto front) for multi-objective optimization problems. In comparison to these techniques, Computational Intelligence Techniques for optimization comprises of evolutionary and swarm optimization techniques and are suitable for black-box optimization problems as these only require the optimization problem to provide the fitness value for solutions. Thus these techniques can be used easily with Process Simulators such as ASPEN, gPROMS, Dymola and other software such as FLUENT, Eclipse E300. These techniques can also elegantly determine the Pareto-front. Though these techniques may not explicitly guarantee the determination of the global optima, they have been reported to determine nearby solutions. In earlier days, the computational complexity of evolutionary techniques used to restrain its usage, but the increase in computational power, especially parallel and GPU computing, have made these efficient in solving complex problems. Majority of these techniques are nature inspired and are modeled to mimic the natural processes. Genetic Algorithm, Simulated Annealing, Particle Swarm Optimization, Differential Evolution are some of the popular algorithms which are widely used to solve real world problems. Although the domain of problems which can be solved using these techniques are countless, I have specifically highlighted some of the examples related to chemical engineering applications that have been reported in the past two years.

Optimal control of dynamic processes is a challenging task which requires real time monitoring of the processes and implementing optimal decisions at regular time instant. Most dynamic optimization problems in Chemical Engineering are modelled as a set of simultaneous differential equations and are used to calculate the process parameters at various interval of time. Classical optimization techniques become quite tedious for such optimal control problems and these have been frequently solved with Computational Intelligence Techniques. Six case studies of fermentation models involving fed-batch reactor encountered in biofuel production of ethanol, pharmaceutical synthesis of protein and penicillin, to treatment of wastewater and sewage sludge have been optimized using back tracking search algorithm (BSA) by Zain et. al [1]. The performance of BSA was reported to be consistently better than other popular algorithms. In the work of Liu et. al. [2], computer aided molecular design (CAMD) was improved using a hybrid version of Genetic Algorithm and Simulated Annealing (GASA) and demonstrated on the solvent design of extractive distillation of a methanol and methyl acetate system.

A significant percentage of global population is lacking fresh water and energy supply through grid. In this regard, reverse osmosis desalination (ROD) plants and renewable energy sources have received immense attention. The optimization of six grid independent hybrid renewable energy systems (GIHREES) [3] using improved bee colony algorithm to be used for meeting energy load and fresh water requirement has been reported. The decision variables included the area swept by the wind turbine blades, the PV surface area, the number of hydrogen tanks, the number of batteries, and effects of integrating water

desalination alongside meeting load demand. Han et.al. [4] have used a multi-objective state transition algorithm to solve the dynamic optimization problem of oxygen and zinc oxide addition in the goethite process for iron precipitation. The maximization of iron precipitation efficiency and minimization of total cost of oxygen and zinc oxide are considered as the two objectives in this case. The decision variables are rate of addition of oxygen and zinc oxide in the reactor. The obtained results provided a better control in terms of cost and efficiency of the process.

There are many other applications where Computational Intelligence techniques have been used such as multi-period heat exchanger network model with a two level method based on Simulated Annealing and rocket fireworks optimization [5], design optimization of solar receiver using Genetic Algorithm [6], optimization of water alternating gas method using Genetic Algorithm and Particle Swarm Optimization [7], optimal operations in solar driven sweeping gas membrane distillation desalination system using Genetic Algorithm, particle Swarm Optimization and Simulated Annealing [8].

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QS Rankings in Chemical Engineering

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QS Rankings are considered as one of the popular ranking and recognition system for any university. The QS world university rankings are evaluated based on six factors namely Academic Reputation, Employer Reputation, Citations per faculty, Faculty Student, International Faculty and International Students [1]. It confirmed Massachusetts Institute of Technology (MIT) as the world's highest-ranked university for a sixth successive year. In doing so, MIT equalled Harvard University's record of consecutive number-one positions. Among the Asian Universities, none of the universities is in top ten.

Now let us discuss about the world rankings in the subject of chemical engineering. The rankings in the subject of chemical engineering are based on Academic Reputation, Employer Reputation, Citations per paper and H-Index Citations. From Table 1 it is inferred that Massachusetts Institute of Technology and Stanford University topped in Employer Reputation and Citations per paper respectively. In Academic Reputation, though University of Minnesota excelled with 100 points, it is not in top list based on overall Score [2]. Compared with 2017, California Institute of Technology dropped by two positions (rank 5 to7) and Kyoto University moved up by one position (rank 6 to 5), whereas remaining universities in top five secured their place [3].

Table 1. World rankings of 2018 in the subject of Chemical Engineering.

Rank	University	Overall Score	Academic Reputation	Employer Reputation	Citations per paper	H-Index Citations
1	Massachusetts Institute of Technology	99.2	98.5	100	98.7	100
2	Stanford University	95.4	91.4	96	100	99.8
3	University of Berkeley	93.3	92.6	89.6	99.1	99.8
4	University of Cambridge	92.8	91.6	98.4	91.7	97.9
5	Kyoto University	91.1	90.9	92.3	89	97
6	University of Oxford	90.7	86.9	97.6	92	96.5
7	California Institute of Technology	90.2	89.7	88.6	97.1	96
7	Imperial College London	90.2	91.8	91.4	87.3	95.4
9	National University of Singapore	89.8	86.2	90.5	92.4	92.7
10	The University of Tokyo	89.4	87.3	92.2	88.5	91.3

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Table 2 concludes that in Citations per paper and in H-Index Citations Nanyang Technological University, Singapore (NTU) excelled among the Asian Universities whereas in Academic Reputation and in Employer Reputation Kyoto University is leading [2]. Rankings among the Asian Universities remained to be stable when compared with 2017 rankings, only change is Seoul National University dropped down by one position whereas Nanyang Technological University, Singapore moved up by one position and equalled with Korea Advanced Institute of Science & Technology (KAIST) [3].

Table 2. Asia rankings of 2018 in the subject of Chemical Engineering.

Rank	University	Overall Score	Academic Reputation	Employer Reputation	Citations per paper	H-Index Citations
5	Kyoto University	91.1	90.9	92.3	89	91.3
9	National University of Singapore (NUS)	89.8	86.2	90.5	92.4	95.4
10	The University of Tokyo	89.4	87.3	92.2	88.5	90.1
11	Tsinghua University	89.1	84.7	91.4	87.4	97.9
14	KAIST-Korea Advanced Institute of Science & Technology	86.8	82.7	87.8	91.7	91
14	Nanyang Technological University, Singapore	86.8	81.1	83.5	95.8	99.8
16	Seoul National University	86.4	80.9	91.1	87	91
20	Tokyo Institute of Technology	85.1	82.9	90.5	84.3	81.2
30	The Hong Kong University of Science and Technology	82.4	79.8	84.3	90	78.1
34	Osaka University	81.8	74.3	85.2	88	89.1

Table 3 summarises that in Academic Reputation, Employer Reputation and in Citations per paper Indian Institute of Technology Bombay (IITB), Indian Institute of Technology Delhi (IITD), and Indian Institute of Science are leading among the Indian Universities respectively. World Rankings of Indian Institute of Technology Guwahati, Indian Institute of Technology Roorkee and Anna University dropped down to 251-300 from 201-250 when compared with 2017 ranking statistics [2].

Among Indian Universities, compared with QS Rankings 2017 statistics Indian Institute of Technology Bombay moved up by one position and stood first in QS Rankings 2018 whereas Indian Institute of Science dropped by one position and settled with second position . Though Indian Institute of Science leading in Citations per paper and H-Index Citations, there is good scope of improvement in Academic Reputation and Employer Reputation [3]. Indian Institute of Technology Guwahati, Indian Institute of Technology Roorkee, Anna University and Institute of Chemical Technology, Mumbai also have good scope of improvement in Academic Reputation and Employer Reputation.

Table 3. India rankings of 2018 in the subject of Chemical Engineering.

Rank	University	Academic Reputation	Employer Reputation	Citations per paper	H-Index Citations
51-100	Indian Institute of Technology Bombay	73.5	75.3	78.6	69.7
101-150	Indian Institute of Science	64.8	61.7	85.8	76.2
101-150	Indian Institute of Delhi	67.3	75.7	77.3	60.6
101-150	Indian Institute of Technology Kanpur	68.4	65.8	73.9	59.8
101-150	Indian Institute of Technology Kharagpur	62.8	66	81.2	72
101-150	Indian Institute of Technology Madras	67.7	65.8	77.8	68.5
201-250	Institute of Chemical Technology , Mumbai	54.6	54.6	83.2	74.2
251-300	Anna University	41.7	59.1	78.1	69.1
251-300	Indian Institute of Technology Guwahati	48.3	55.3	77.9	63.7
251-300	Indian Institute of Technology Roorkee	49.9	57.3	81	67.2

References:

1. https://www.topuniversities.com/university-rankings/world-university-rankings/2018
2. https://www.topuniversities.com/university-rankings/university-subject-rankings/2018/engineering-chemical
3. https://www.topuniversities.com/university-rankings/university-subject-rankings/2017/engineering-chemical

Guwahati Regional Centre Activities

REFLUX 2018, the Annual Chemical Engineering Symposium

The Sixth edition of REFLUX (REFLUX 2018) in association with Indian Institute of Chemical Engineers-Guwahati Regional Centre (IIChE-GRC) was held from March 16-18, 2018 at the Department of Chemical Engineering, Indian Institute of Technology Guwahati. The conference was majorly supported by AFCONS Infrastructure Limited, Labguard India Pvt. Ltd. and Numaligarh Refinery Limited. With a focus on the development and application of sustainable solutions, the theme of the REFLUX 2018 was *Transpiring Sustainability*.

The event brought together some 400 participants from all over the country. It also provided a valuable networking opportunity and set the stage for further collaboration among various academic institutions.

Prof. Sirshendu De, Professor, Department of Chemical Engineering, Indian Institute of Technology Kharagpur was the Chief Guest for the inaugural event. **Prof. Gautam Biswas,** Honorable Director, IIT Guwahati presided over the function. Welcoming the Chief Guest and other dignitaries, **Prof. Bishnupada Mandal,** Head of the Department briefed on the activities of the department. **Dr. Partho Sarathi G. Pattader,** Faculty coordinator, REFLUX 2018 delivered the welcome address while **Shri. Devanshu Nema,** Convener, REFLUX 2018, briefed on the activities of the REFLUX. **Shri. Shubham chaturvedi,** Convener, REFLUX 2017 delivered vote of thanks.

Prof. Sirshendu De delivered his inaugural lecture and highlighted the need for field implementation and ways to establish and sustain start-up incubation. An Open House session with the Chief Guest was organized on March 17, 2018 to learn on engaging with real world issues in relation to technology transfer and field implementation. **Mr. Hande Vidyabhushana,** Head Research Group, Simulation Solutions, Siemens Corporate Technology, Bangalore discussed on the importance of sustainability metric as a new dimension of product selection. **Prof. Gautam Biswas,** delivered the plenary lecture on day three of REFLUX 2018 on March 18, 2018. His presentation, entitled "Analysis of the Influence of Superheat, Gravity and Electric Field on Bubble Growth in Film Boiling" summarized research findings of different studies on transition in bubble release pattern and multimode bubble formation in saturated pool boiling heat transfer. The fourth plenary lecture was about sustainable product-service system design by **Dr. Sharmistha Banerjee,** faculty from the Department of Design, IIT Guwahati, to design ecoefficient product-service systems for social equity and cohesion.

A workshop on Research methodology was organized on March 16, 2018. Workshops on ASPEN Plus and MATLAB were held on March 17, 2018. A training workshop on Latex was organized on March 18, 2018. These workshops were attended by more than 150 participants. As part of these workshops, the participants were provided an in-depth understanding about various technical software and research & writing tools. The symposium also addressed a variety of topics in terms of various events relevant to the main theme including oral and poster presentations, case studies, start-up show case, quiz competitions and ideation challenge.

Valedictory Function was held on March 18, 2018 with **Prof. P. S. Robi**, Deputy Director, IIT Guwahati as Chief Guest of the event. **Dr. R. Anandalakshmi** conveyed her gratitude to all participants, plenary speakers, panelists, sponsors and presenters in her capacity as faculty coordinator, REFLUX 2018. She also extended her thanks to the core committee of REFLUX 2018 and the faculty members of Department of Chemical Engineering for their efforts and expressed her satisfaction with the interactive nature of the discussions. She expressed confidence that the networking would continue going forward and yield in providing sustainable solutions to the society.

We invite articles for the upcoming newsletter. Please write to iiche.grc@iitg.ernet.in for further details. The articles are published as provided by the authors. The opinions expressed in the articles should not be considered as endorsed by Indian Institute of Chemical Engineers – Guwahati Regional Centre or Indian Institute of Technology Guwahati.

IIChE newsletter is available at http://www.iiche.org.in/pdfs/NLVol9.pdf

State-of-the-Art in Refinery Operations

Organized by
Department of Chemical Engineering, Indian Institute of Technology Guwahati &
Indian Institute of Chemical Engineers – Guwahati Regional Centre

In association with
Guwahati Refinery

Date: April 4, 2018 (Monday)

Venue: Conference Centre, Indian Institute of Technology Guwahati

Session No.	Name of the Expert	Title of Expert Lecture	Time
	Introduction		10:00 AM -10:15 AM
1	**Mr. Lalan Kr. Paul**, Chief Production Manager, Guwahati Refinery	Overview of IOCL and Guwahati Refinery	10:15 AM – 11:00 AM
	Break for Refreshments		11:00 AM – 11:15 AM
2	**Prof. Anugrah Singh**, Dept. of Chemical Engineering, IIT Guwahati	Application of CFD in Petroleum Industry	11:15 AM – 12:00 Noon
3	**Mr. Bhupesh Mishra**, Senior Production Manager, Guwahati Refinery	Refining Technology	12:00 Noon – 12:45 PM
	Lunch Break		12:45 PM – 1:45 PM
4	**Mr. Abhijit Singh Chowdhury**, Depy. Gen. Manager (Instrumentation), Guwahati Refinery	Industrial Automation	1:45 PM – 2:30 PM
5	**Prof. Pakshirajan Kannan**, Dept. of Biosciences and Bioengineering, IIT Guwahati	Biological treatment of oil and gas industry wastewater for value addition and resource recovery	2:30 PM – 3:15 PM
	Break for Refreshments		3:15 PM – 3:30 PM
6	**Mr. Manoj Ray**, Depy. Gen. Manager (Fire & Safety)	Industrial Safety	3:30 PM – 4:15 PM
7	**Dr. Vimal Katiyar**, Dept. of Chemical Engineering IIT Guwahati	Recent developments in Petrochemicals (Tentative)	4:15 PM – 5:00 PM


Sewage Treatment plant at Anna University
Treatment Scheme


IIT Guwahati