9th World Congress of Chemical Engineering, Seoul, Korea

Game Changing Chemical Engineering for our Sustainable Future

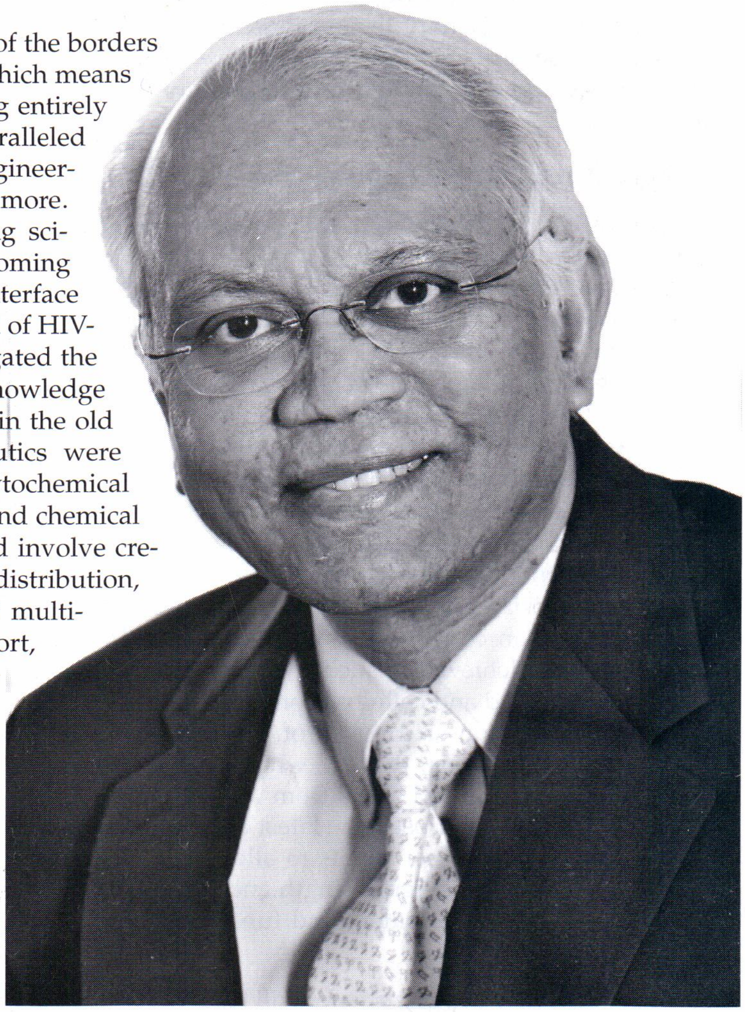
- Dr R A Mashelkar

Dr. R. A. Mashelkar delivered the inaugural plenary lecture '**Game changing chemical engineering for our sustainable future**' at the recently concluded 9th World Congress of chemical engineering in Seoul. The congress, attended by over 1500 Chemical Engineers, had around 5000 presentations.

In his plenary lecture, Dr. Mashelkar set out five megatrends that, according to him, will drive chemical engineering in the 21st century. He said that chemical engineering will become borderless, inclusive, integrative, innovative and responsible.

Borderless chemical engineering

Dr. Mashelkar had earlier predicted disappearance of the borders between chemical engineering and adjacent sciences which means that a chemical engineer will move seamlessly, creating entirely new frontiers at the interface of disciplines with unparalleled diversity and complexity, such as "cell and tissue engineering", "molecular information engineering" and many more. The lecture was titled 'Seamless chemical engineering science: the emerging paradigm.' These predictions are coming true today with papers such as chemical engineering interface with virology, with the immune systems, on the control of HIV-1 pathogenesis. Dr. Mashelkar said that he had propagated the idea of breaking borders even between traditional knowledge systems and chemical engineering. He observed that in the old traditional medicinal systems, plant based therapeutics were used. He had proposed the creation of the field of phytochemical reaction engineering, which interfaced plant sciences and chemical engineering. He had pointed out that this field would involve creating designer plants, optimizing composition and its distribution, control of growth, pharmacodynamics in the case of multi-component mixture, understanding absorption, transport, permeation, binding and mechanism of action, designing new delivery systems.



Dr. Raghunath Anant Mashelkar is the President of Global Research Alliance and also the President of India's National Innovation Foundation. He is also appointed as the first Chairperson of Academy of Scientific and Innovative Research (AcSIR).The 2000 Padmabhushan awardee is a CSIR Bhatnagar fellow at NCL.

Inclusive chemical engineering

Referring to his paper, co-authored with the late legendary C.K. Prahalad in the July-August issue of Harvard Business Review (HBR) titled `Innovation's Holy Grail', Dr. Mashelkar observed that inclusive growth is a big challenge. "How do we `include' 2.6 billion people, whose income levels are less than US $ 2 per day so that we could create an equitable world? This can happen only if our profession is able to help create access equality despite income inequality," stated Dr. Mashelkar. This illustrated the strategic shift that was taking place, emphasizing `more from less for more people, not just for more and more profit' can be

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achieved. This 'more from less for more (MLM)' theme had caught on in the world. In fact, World Economic Forum had a symposium on `More from Less for More' within six months of appearance of Prahalad-Mashelkar paper in HBR. "How can chemical engineers join in? Can we make a recombinant DNA Hepatitis B vaccine, not for $ 20 per dose but for 40 cents per dose; an artificial foot, not for $ 10,000 but only for $ 30; complex diagnostics not costing $ 10 per test but just 10 cents per test?" challenged Dr. Mashelkar. Chemical engineers have already contributed to making such ultra low cost but high quality products. The plenary lecture illustrated as to how the strategic shift to creating 'affordable excellence' was taking place and how the chemical engineers will lead this process.

Integrative chemical engineering

Illustrating the challenge of integrative chemical engineering, Dr. Mashelkar said that if we have to move from hydrocarbon based economy to carbohydrate based economy then the challenge is to create a "bioeconomy" leading to our "biofuture" for tmankind. "We will then require many fundamental breakthroughs in plant sciences. For instance, the current efficiency of capture of light energy by the process of photosynthesis is less than 2%. Can engineered genes from plants and photosynthetic bacteria increase this efficiency? Can we manipulate the genes involved in nitrogen fixation to increase biomass content of plants? Can plants be engineered for rapid growth with drought and high and low temperature stress? Can co-regulation of lignin and cellulose biosynthesis be achieved in such a way that lignin content can be reduced and cellulose content increased?" he posed. Dr. Mashelkar said that Prof. Jay Keasling from University of California, Berkely, who would speak on the subject of 'Advanced Fuels from Advanced Plants' at the same venue, had used the latest advances in synthetic biology to engineer plants to alter their biomass composition, including lignin length and content, cellulose and hemicellulose content and functionalisation of hemicellulose.

These advances in plant science will form the foundations of advanced biorefineries. These can be positioned as "future processing complexes" that will use renewable agricultural residues, plant based carbohydrates and ligno-cellulosic materials as feed stocks to produce a wide range of chemicals, fuels and bio – based materials, Dr. Mashelkar stated But this task will put to test the ultimate system engineering and integrative skills of the chemical engineers. Advanced bio-refineries will have to creatively integrate the knowledge in plant genetics, biochemistry, biotechnology, biomass conversion chemistry, process engineering and separation technology, he stressed. An equally challenging task will be forging creative partnerships between enterprises dealing with fuels and energy as well as chemicals and materials with enterprises managing agriculture, agro-marketing and food chain. Dr. Mashelkar emphasised that to succeed, the chemical engineers will have to manage advances in fundamental science with the complex interplay between energy, materials, environment and society associated with a carbohydrate based economy. It was obvious that being 'borderless' and being 'integrative' were two essential pre-requisites.

Innovative chemical engineering

"This type of engineering goes beyond mere technological innovation involving new processes and new products. These will involve business model innovation, system delivery innovations, workflow innovations, organizational innovation and so on. The chemical engineers will have to learn to creatively synergize the combination of these different types of innovations for maximum effect. For example, creating affordable drinking water through a scientific breakthrough can lead to a successful technological innovation. But selling that water, not as a product, but as service, was a business model innovation. In the future, chemical engineers will see innovation opportunities moving further downstream in the value chain with increasing diversity, i.e. from chemicals to materials and systems to services and solutions; such downstream integration will increasingly require diverse types of innovations in developing customer value chains," said Dr. Mashelkar.

Dr. Mashelkar particularly emphasized the need for a game changing disruptive innovation rather than just incremental innovation. This required an out-of-the-box thinking. He illustrated this by the example of 'paper based diagnostics', created through a printing technology, which does away with electronics based expensive instruments. He showed as to how in Pune in India, something as mundane as garbage was linked to something as advanced as 3-D printing, a new technology that heralds

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the arrival of 'additive manufacturing'. He showed how a disruptive thinking had led to the creation of carbon nano-tubes by using (otherwise polluting) exhaust gases from a chimney or from an auto exhaust, thus reducing the cost of carbon nanotubes from US $ 50 to US $1! He urged the 'innovative' chemical engineers of the future to be 'disruptively' innovative.

Responsible chemical engineering

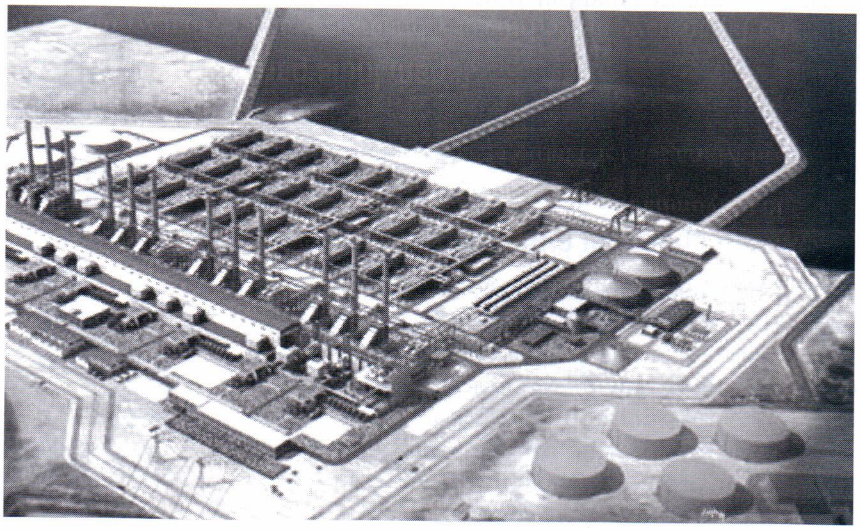
Dr. Mashelkar said that the first challenge was that of managing the perceptions about our industry. According to risk expert Paul Slovic, people in the US and other industrialized nations saw themselves as increasingly vulnerable to the risks posed by the chemical technologies. Dr. Mashelkar said that he was personally involved in looking closely at human tragedies in India due to the accidents in Indian chemical industry. And they were the worst two in Indian history.

The first was the Bhopal gas tragedy. An accidental leakage of the deadly methyl isocyanate in the early hours of 3 December 1984 killed and incapacitated thousands of people. This was rated as the worst industrial disaster in human history. Some have called it the 'Hiroshima of chemical industry'. Dr. Mashelkar recalled that he had served as the technical assessor for the inquiry commission that was set up by the government. Within three days of the accident, Dr. Mashelkar said, that he was standing on the accident tank, which was emptied. Next to that was another tank with 40 tons of MIC. One did not know at the time, whether it was a ticking time bomb? Dr. Mashelkar recalled that they had to deal with a society that was scared – people that were angry. For a young engineer, it was a sobering experience. The second was the accident at Maharashtra Gas Cracker Complex almost ten years later, which killed thirty four people. Dr. Mashelkar recalled that he was appointed as the Chairman of the Inquiry Committee to investigate the cause of the accident and suggest measures so that such accidents could be prevented in future. These were challenging assignments for him. They taught him as to what 'responsible chemical industry' should be and what the duties and obligations of 'responsible chemical engineers' should be.

Dr. Mashelkar exhorted the chemical engineers toincreasingly and intensively integrate with corporate leaders, regulators, and other professional bodies to create cultures that deliver real improvements in health, safety and environmental performance. "As 'responsible' chemical engineers, we cannot afford to let such disasters happen again. But besides such onetime disasters, continuous disasters are looming large. Climate change, global warming, etc. pose daunting challenges for the very survival of humanity. The chemical engineers will have to be at the centre stage, and not at the periphery, in making our dreams of 'carbon neutral cities' and 'low or no carbon economy' come true," he said.

A simple and low energy method to desalinate water

- Works without membranes or large amounts of energy
- Potential application in drought stricken countries



A new method for the desalination of sea water was recently reported by a team of American and German researchers in the journal *Angewandte Chemie*. In contrast to conventional methods, this technique consumes little energy and is very simple. This electrochemically mediated seawater desalination is based on a system of microchannels and a bipolar electrode. According to Richard Crooks (The Univ. of Texas at Austin), Prof. Ulrich Tallarek (Univ. of Marburg), and their colleagues, the new electrochemical process works without membranes or large amounts of energy. The researchers force the water through a system of two microchannels that are about 22 µm wide, an auxiliary channel and a branched working channel, flowing on to the outlets. The two channels are electrically connected through a bipolar electrode. The auxiliary channel is connected to a voltage source, the working channel is grounded, and a potential difference of 3.0 V is established between the two channels.

The structure of the channel system is critical. The electrode extends out into the branch point of the working channel. Because of the voltage, some of the negatively charged chloride ions in the seawater are oxidized to neutral chlorine at one end of the bipolar electrode. In the narrow channel system, this creates a zone that has a lower number of negatively charged ions, which results in an electric field gradient that directs the positively charged ions in the seawater into the branching channel. Physics requires the electroneutrality within the microchannels to be maintained, so the anions follow the positive ions into the branched channel. The water flowing through the branch is thus enriched with ions, while the water continuing through the main working channel is partially desalinated. The amount of energy required for this new technique is so low that the system can operate with a simple battery. In contrast to reverse osmosis, it is only necessary to remove sand and sediment from the seawater. No further treatment, disinfection or addition of chemicals is needed. A simple parallel arrangement of many microchannel systems should allow for an increase in water throughput.

The United Nations estimates that one-third of the global population already lives in water-stressed areas; this figure is expected to double by 2025. For a country like India which is surrounded on three sides by sea and, one which frequently suffers from droughts and water paucity, such technology could benefit its people immensely.

Discovery of a phenolic reaction promises to boost pharma productivity

A new chemical reaction has been discovered that has the potential to lower the cost and streamline production for a whole range of chemicals. Researchers from the University of Texas at Austin (UTA), which was responsible for this discovery, said that the reaction resolves a long-standing challenge in organic chemistry in creating phenolic compounds, usually known as phenols, from aromatic hydrocarbons quickly and cheaply. "This is a chemical transformation that is underdeveloped and at the same time pivotal in the production of many chemicals important to life as we know it," said Dionicio Siegel, an assistant profes-