Fuelling China's future

Min Enze helped to kickstart China's industrial boom. Fifty years on, his research focuses on tackling the environmental damage of development, reports Bea Perks

The story of a young boy in south-western China in the 1920s who went on to become one of the country's leading chemical engineers reflects the extraordinary political, cultural and economic progression of a country widely tipped as the next global superpower.

Min Enze, now a highly regarded senior member of the Chinese Academy of Sciences and senior consultant at the Sinopec Research Institute of Petroleum Processing in Beijing, was born in February 1924, at the dawn of the Chinese civil war (which was to rage on until 1950 with the birth of the People's Republic of China).

He went to school during the civil war, to university during the second world war, and completed a PhD in the US, during which time his homeland became a communist state. On returning to China, Min took on the Herculean task of keeping pace with the world's refining industry despite stifling trade restrictions. Refining technology had to be developed from scratch, since much of the outside world would have nothing to do with this new state.


MIN ENZE

Min Enze as a PhD student at Ohio State University, US, in 1948

In short

- **Min Enze was studying for a PhD in the US when his homeland became the People's Republic of China.**
- **He had been working at the ministry of petroleum's research institute in Beijing for three years before the country's biggest oil field was discovered in 1959.**
- **He is a senior member of the Chinese Academy of Sciences and a member of the Chinese Academy of Engineering**
- **From 1996-2004 professor Min was chairman of the academic committee at the Sinopec Research Institute of Petroleum Processing (RIPP)**

Going green

It's a very different story today – China is now the third largest trading partner of the US and, in terms of nominal GDP, the fourth largest economy in the world. But such a meteoric rise comes at a price, and China is now counting the environmental costs. According to the World Bank, Chinese cities make up 16 of the world's 20 most polluted. The World Health Organization estimates that up to 17 per cent of deaths in the country are linked to environmental health risks.

Min's research focus is firmly on green chemistry, and particularly on biodiesel production. 'I have always closely followed scientific advancement worldwide, and became interested in green chemistry in 1995,' he says. In that year he chaired a consortium to investigate sustainability in the chemical sciences, sponsored by the Chinese Academy of Sciences' Chemistry Division.

MIN ENZE

83 years and counting

'I have always closely followed scientific advancement worldwide'

His interest in sustainability is driven by environmental damage, rather than by the threat of limited oil reserves. Likewise, his main driving force for biodiesel development is to stem environmental damage, rather than find alternatives to crude oil. However, with dwindling reserves and rising oil prices, biodiesel could become economically as well as environmentally viable. 'A fortuitous benefit of rising oil prices ... a shot in the arm for green chemistry,' says Min.

Young ambition

Min was born in Szechuan Province, where the main industry in the 1920s was agriculture. He didn't start off wanting to be a chemist but started studying civil engineering at China's National Central University. 'I wanted to build a bridge across the Yangtze River in memory of my mother,' he recalls. (Min's mother died when he was at middle school.) But his mother's brother, a banker, didn't think much of the bridge idea. He wanted his nephew to become an industrialist, so in 1943 Min switched to chemical engineering, an unusual degree choice at the time, he says. With Szechuan's reliance on agriculture, Min – who clearly had grand aspirations from an early age – shelved his plans for a bridge and decided to build a fertiliser factory.

When he graduated in 1946, there were no jobs for chemists in his home town of Chengdu and chemistry graduates were expected to become school teachers. It's very different now; the city is a key manufacturing centre for the pharmaceutical, chemical, metallurgy and food processing industries.

Chemical progress

Leading Chinese medicinal chemistry contract researcher ChemPartner has opened a facility in the city, citing the importance of nearby universities. And construction of a \$12 million (£6 million) facility to house the city's Institute for nanobiomedical technology & membrane biology is about to start, in association with Shuguang Zhang, associate director of the Center for Biomedical Engineering at Massachusetts Institute of Technology, US.

German chemical giant BASF also has an office in Chengdu. BASF is a striking example of the potential that overseas investors see in China: it employs over 4000 people in the country, operating 16 wholly owned companies, seven joint ventures and 14 production sites.

Cleaning up

Min was lucky. After he graduated, his influential uncle got him a position as an apprentice at a soap factory in Chongqing (at that time a city in Szechuan province and now a provincial-level municipality in its own right). Perhaps his uncle had been looking into a crystal ball again: what Min learnt at the soap factory has been very helpful with his biodiesel work, he says.

While Min was at the soap factory, a project was set up in Shanghai to train chemical engineers for the dyeing and printing industry. Students were tempted with the promise of foreign travel. 'This was a very attractive opportunity,' he remembers. Min left the soap factory for a textile dyeing and printing factory in Shanghai, where he met up again with a former university classmate, Lu Wanzhen, who was later to become his wife and a very successful chemist in her own right.

Foreign shores

After the second world war the Chinese government planned to send 1000 students to the US. In fact, the students had to provide the cost of travel, tuition and living expenses themselves; the government's only contribution was to exchange the funds into foreign currency, which was in very short supply at that time. Fortunately Min was able to arrange a bank loan which got him a passage to the US and living expenses. (The loan was easy to repay, he says, because massive inflation had turned the loan into peanuts.)

So in 1947 the young man set sail for the US and began a masters degree at Ohio State University's department of chemical engineering, which then progressed to a PhD. The year before he left China, Lu Wanzhen had also left for the US. She was studying at the University of Illinois at Urbana-Champaign by the time he arrived.

So there they were, two nationally acclaimed young chemical engineers enjoying the opportunity of a lifetime – working alongside their internationally acclaimed peers in the US. Most of their fellow Chinese academic superstars made every effort to stay in the US. But that wasn't for Min and Lu. They would have bucked the trend and returned to China, to get married and launch their careers, were it not for international politics.

MIN ENZE

World's first commercial magnetically stabilised bed unit for purification of caprolactam

Political upheaval

After the founding of the People's Republic of China in 1949, the US refused to let its Chinese students leave – unwilling to let them take the skills and knowledge they'd picked up back to what was now communist China.

So Min and Lu were trapped. They married in the US in 1950 and both graduated with PhDs from Ohio State University the following year.

Chinese nationals were no longer permitted student visas in the US, so the young couple had to find work. Min worked for a chemical company in Chicago for four years, where he investigated ways to prevent corrosion and deal with the problem of ash deposits in boilers. He says that this industrial experience was invaluable, and not something he could have picked up in a US university or in China at the time.

'Prisoners of war'?

Min and Lu might still be in the US, were it not for their reclassification as, effectively, prisoners of war. Finally, the US agreed to release them in return for US prisoners of war being held by the Chinese following the Korean War (1950–53).

In 1955 Min and Lu went home, although more than 90 per cent of their 1000 or so fellow students had chosen to stay. Whereas the US had feared Chinese students would steal all their best ideas, the new returnees found that Chinese institutions were sometimes reluctant to hire staff who'd just arrived from the US and might be spying for their new friends in the West, and in the beginning jobs were hard to come by.

'In 1959, China discovered Daqing, the biggest oil field in the country'

Petroleum processing

In 1956 Min and Lu found positions at the Ministry of Petroleum's newly established research institute in Beijing, which later became Sinopec RIPP. The institute was built on what had been farmland, and was founded before China had discovered crude oil – the fuel source at that time was oil shale and coal.

'Fortunately, in 1959 China discovered Daqing, the biggest oil field in the country,' says Min. 'That provided the opportunity for research. We wanted to build our own refinery.' The boom in Chinese chemistry really started with the discovery of Daqing, says Min. 'Once China had that resource it took off, so now there is a refining plant in virtually every province in China.'

Crude oil lights the touch paper

With the discovery of Daqing, Min was instrumental in developing major refining technologies needed by industry.

He is widely respected for having laid the technical foundation of petroleum refining catalysts in China. He developed cracking catalysts, including spherical aluminium silicate catalysts for aviation fuel, and micro-spherical Si–Al catalysts for the production of petrol, diesel and liquefied petroleum gases.

In the 1960s, he developed spherical Si–Al cracking catalysts for a moving bed reactor. These provided a superior alternative to the imported Russian catalyst relied on at the time and halved the price of catalysis.

Later, Min developed microspherical Si–Al catalysts for a fluidised bed reactor, incorporating the novel step of drying followed by gelation, which enabled a continuous production process. At the same time he solved key problems with particle size distributions and attrition-resistant strength of the catalysts. All of which resulted in an 8000 tonnes/year catalyst plant. Remarkably, it took only five years from the development of the catalysts to plant completion.

Towards the end of the 1960s, Min developed a series of zeolite materials for cracking catalysts. These heralded a technological revolution in China's refining industry, and triggered large increases in petroleum product yields.

Through the 1970s and 80s, Min led development of manufacturing technologies for new generations of cracking catalysts. In 1985 he was awarded China's second rank national award for science and technology progress for developing a zeolite catalyst called Y–7. The catalyst had higher hydrothermal stability than competitor's catalysts at the time. China's national awards are a highly prized mark of government recognition.

Min is no stranger to top national awards. In 1995, a hydrothermally-stable zeolite called ZRP that he and his colleagues developed was recognised by the state Ministry of science & technology as one of the ten most important science and technology achievements in China.

By the 1980s, it had become clear that chemical processes which eliminate pollution at source rather than post-treatment were needed. Min, who was by now vice-president and chief engineer at Sinopec RIPP, called for directed basic research and drew up a road map for technology innovation.

He led a five-year National Natural Science Foundation of China research project to develop green chemical technologies, with achievements including the development of an amorphous nickel-based alloy and a magnetically stabilised bed reactor to produce caprolactam, a precursor of nylon-6. Crude caprolactam contains several unsaturated compounds, including 1,2-cyclohexanedione and 2-hydroxycyclohexanone, which cannot be extracted or distilled, but can impair the properties of nylon-6. So purification of crude caprolactam is essential; this can be done by hydrogenating the unsaturated compounds catalysed by Raney nickel in a slurry reactor, and then removing the hydrogenated compounds by distillation. The process has low hydrogenation efficiency and uses a lot of catalyst.

Min's team developed a novel hydrogenation process by combining amorphous Ni-based alloy catalysts and a magnetically stabilised bed reactor. The end result was a process that is up to 10 per cent more efficient and uses 70 per cent less catalyst than the original process. The team says the new process can also be extended to other areas of petrochemical processing.

2003 saw construction of the world's first industrial magnetically stabilised bed reactor for caprolactam hydrofinishing. The reactor produces 70 000 tonnes per annum of caprolactam. In 2005 these achievements won that year's only first class award for national technological invention – one of the most highly prized of the government's national awards.

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COLIN CUTHBERT / SCIENCE PHOTO LIBRARY

Min's main focus today is biodiesel

The philosophy of hard work

Min laughs when asked which of his many achievements he is most proud. 'It's hard to choose one,' he says, without boasting. 'There is an old philosophy that the most important thing is to be diligent,' says Min. 'You don't have to be cleverer than anybody else; you have to put more effort in.'

University education is changing in China. There was a time when would-be scientists in China dreamt of studying in the West, and many stayed there, to ensure success. Now, Western scientists, especially chemists, marvel at developments in China, where universities and new departments are springing up, and where industry is investing heavily.

'The attractiveness of the US is becoming less by the year as China takes off,' says Min. He has supervised 30 PhD students at the Research Institute of Petroleum Processing, a surprisingly small number for such a long career, but PhDs are a relatively recent introduction to China's research institutes. Until 1982, students took masters degrees only: 'It was difficult to train students up to PhD standard within the constraints of the education system,' says Min, who has also supervised about 60 masters students. Min is keen for his students to take up postdocs abroad for a year or two and currently has a student working in Germany.

Back to nature

Min's focus is now firmly on China's environmental clean up. Since the start of the 21st century Min has focused mainly on biodiesel. He has developed a near-supercritical-pressure process for manufacturing biodiesel, laying the foundations for an industrial unit.

Producing biodiesel fuel by developing oil-bearing plants will turn agricultural and forestry products into industrial products, says Min, which will help readjust China's agricultural structure, increase farmers' incomes and protect the environment. He's almost come full circle; he never did build that fertiliser factory, but Min might end up working with farmers after all.