



In Memoriam: Kuo King Wang Memorial Tribute



K.K. Wang in the 1970s.



In 1970, K.K. joined Cornell University as an associate professor in the Sibley School of Mechanical Engineering to teach courses and conduct research related to manufacturing. Around that time, the Eastman Kodak Company was developing a revolutionary new product which would be a reusable, low-cost, pocket-sized camera. The camera was mostly plastic, made by injection molding. In trying to set up mass-producing the product at a low cost, it was found that the mold could not be fully filled, and the molded parts contained defects. The company used trial and error to troubleshoot but could not find a solution, thus delaying the introduction of the product.

Kodak's CEO at the time, a Cornell alumnus and member of the Advisory Board for the Dean of Engineering, asked the Dean if it would be possible for academia to help develop a scientific basis for mold design and process control. The message was passed on to the Department of Mechanical Engineering and eventually reached K.K. for consideration. The Director of Industrial Liaison in the Dean's office facilitated discussions with Kodak's technical staff, resulting in the Cornell team submitting a proposal to Kodak. The technical staff at Kodak reviewed and agreed to the proposal, but corporate management ultimately did not sign off, citing concerns over the intellectual property rights of the research that would be generated.

This turned out to be fortuitous, as K.K. and a senior faculty colleague in Mechanical Engineering submitted a proposal to the National Science Foundation (NSF) instead. Their proposal was accepted in 1974, and this was the birth of the Cornell Injection Molding Program (CIMP) [1]. Along with K.K., the other members of the core research team in the first 15 years were S.F. Shen (Mechanical and Aerospace Engineering), Claude Cohen and Don Koch, from both Chemical Engineering and Neil Heiber from Mechanical Engineering.

Ultimately, a total of 11 NSF grants provided \$3.6 million of continuous support for CIMP through 1998. NSF's exceptionally long support of CIMP was a result of the broad industrial support it was receiving, and the project was producing results that significantly improved manufacturing processes.

From its inception, CIMP's goal was to establish a scientific basis for the injection molding process. The existing knowledge of rheology and non-Newtonian fluid mechanics at the time was not able to predict the process behavior with any accuracy. From the outset, the CIMP research team took existing knowledge and techniques used in thermal sciences and rheology and tested them through a series of specially designed experiments. All theoretical analyses were tested and verified by experimental results. In this research process, the CIMP team developed two new instruments to characterize the basic material properties needed for flow analysis. These instruments, along with companion simulation software, are still used in the injection molding industry today.

In keeping with the idea of solving real-world problems, the CIMP Industrial Consortium was established in 1978 [2]. The

Kuo King ("K.K.") Wang was a pioneer in injection molding of polymers and non-polymer materials that helped the manufacturing industry around the world evolve to its current practices. He built an interdisciplinary research team at Cornell University that used a scientific base for analyzing the injection molding process by integrating and extending existing knowledge. He also pioneered and established a renowned consortium of global corporations. The corporations incorporated the research findings into their manufacturing processes. The relationships continued for decades and the research results are widely implemented in manufacturing around the world.

K.K. Wang was born in China in 1922. He received his bachelor's degree in Engineering from the National Central University in 1947. His college years were difficult as the war raged and food was scarce. The university campus moved twice to avoid the worst of the war. After obtaining his degree, he moved to Taiwan where he went to work for the Taiwan Shipbuilding Company. This was a relatively short period of time in his life, but a very significant one for two reasons. First, he met and married his wife, Cindy. And second, he was sent around the world to visit partners and customers of the Shipbuilding Company, including several trips to the U.S..

Looking for more opportunities, K.K. and Cindy moved to the United States and worked for the Walker Manufacturing Company. The company produced automobile exhaust systems. It was particularly difficult to manufacture parts that had an elbow joint or any kind of bend. While K.K. worked on that during the day, he pursued a master's degree in the evening at the University of Wisconsin. After receiving his degree, he believed he needed more education in order to advance his career, so he made the decision to return to school full-time to pursue a doctorate degree, which he received in 1968. He then joined the faculty as an assistant professor in Mechanical Engineering.

founding members were Kodak, Cincinnati Milacron, General Electric, General Motors, and Xerox. The consortium reached its peak in 1986 with 35 member companies. Many of the companies remained members until the Consortium ended with K.K.'s official retirement from Cornell in the early 1990s. After that, K.K. continued working for CIMP for over a decade as there were three active projects at that time, all extensions of CIMP's earlier work.

To apply the research to manufacturing processes, computer simulation programs were developed as a by-product of the research. These software applications were highly sought after by the CIMP Consortium members. As the companies started to use the software, it became a burden to the CIMP research team to provide software support. This became an opportunity for one of K.K.'s Ph.D. students, Dr. V.W. Wang (no relation to K.K.), to start a company, AC Technologies, which focused on developing commercial-grade software that would transfer and extend the technologies developed by CIMP to industrial applications. The five founders of A.C. Tech were K.K., S.F. Shen, V.W. Wang, Claude Cohen, and Neil Heiber. Many CIMP members acquired AC Technologies' software. The initial products included a mold-filling simulation along with simulations of the packing and cooling phases of the injection molding process. The company's materials lab also provided materials property data for various grades of polymers to be injected.

Over time, the product name morphed into the software called C-MOLD. It was the leading product in the field at the time. Eventually, the company changed its name to C-MOLD. AC Technology/C-MOLD was one of the earliest spinoff companies from Cornell University. C-MOLD was acquired by Moldflow, Inc. in 2001. Moldflow was then acquired by Autodesk in 2008.

Today, C-MOLD software, based on CIMP's research results, can predict the behavior of the injection molding process accurately and is used in manufacturing throughout the world. The old mold trials that used to take weeks or months can be done in hours or days on a computer with more accurate results. As an example, developing a production mold for a laptop computer casing typically took 3–6 months. A large plastic part such as a bumper or instrument panel of a car took over 6 months and could cost millions. With the new simulation tools, these tasks have been reduced to days or even hours, and a physical mold trial is often not necessary.

The output of CIMP is still a prevailing force in injection molding around the world after many decades. For example, precision injection molding and modeling technology blossomed in Taiwan after the 2000s when glass lenses were replaced by plastic lenses in cameras. The technology pioneered by CIMP was the cornerstone of this revolution, which has reached all corners of the world. Smartphones today use at least three compact cameras with five–six tiny plastic lenses, of which billions are produced each year. Residual stresses in the lenses must be predicted and minimized via simulation before molding. CIMP's latest research results in the modeling and prediction of molding stresses were incorporated into the computer-aided engineering (CAE) and analysis software. This precision molding technology was used by LARGAN and GSEO in Taiwan to manufacture plastic lenses that are used in Apple's iPhones and laptops. Plastic optics have been rapidly adopted by many industrial and consumer products due to this advancement in CAE tools.



An instrumented mold is installed to study warpage of injection-molded plastics at Cornell CIMP in the 1990s.

K.K. received numerous awards and accolades over his long career, most prominently being elected a fellow of the National Academy of Engineering in 1989. Beyond that, he had received the Blackall Machine Tool and Gage Award from the American Society of Mechanical Engineers in 1968, Adams Memorial Membership Award of the American Welding Society in 1976, and the first TRW Fellowship in manufacturing engineering in 1977. He was also a fellow of the American Society of Mechanical Engineers, Society of Manufacturing Engineers, and the International Institution for Production Engineering Research.

Outside of work, K.K. was dedicated to his family and actively involved with his three children. Throughout his career, he always made it a point to be home for dinner when he wasn't traveling. He attended school meetings, followed his three children's extracurricular activities, and was always available to help with schoolwork if asked. K.K. and his wife Cindy spoke Chinese with their children at home to be sure the children would be conversant in Chinese.

K.K. and Cindy traveled the world together, having visited every continent except Antarctica. After they both retired, they continued traveling near and far with friends and family. They took some memorable trips to their native China, visiting places they had learned about as school children but had not seen.

K.K. passed away in October 2022. He was predeceased by Cindy, his wife of 60 years.

Gigi Wang, March 2024

References

- [1] National Academy of Engineering, K.K. Wang Memorial Tribute, 2024.
- [2] History of Cornell Injection Molding Program (CIMP), Cornell University Library. <https://ecommons.cornell.edu/items/4b28fb8e-6bad-48a4-820e-c6fc3d52b87>