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Editorial

In Memory of Professor Ferdinand Freudenstein, 1926–2006

In the spring of 1999 Professor Marco Ceccarelli invited Professor Ferdinand Freudenstein to present the opening plenary lecture at the International Symposium on History of Machines and Mechanisms, sponsored by IFToMM and scheduled to be held in May 2000 in Cassino, Italy.

Professor Ceccarelli requested that the lecture contain a short overview of the field in relation to Professor Freudenstein's personal history. However, Professor Freudenstein had retired from Columbia University three years earlier, and by the time the invitation came his health was such that it would have been difficult for him to travel to Europe. Still he accepted the invitation, and in May 1999, with the assistance of his wife Lydia, and a colleague, Professor Richard Longman of Columbia University, he made a videotape of his plenary lecture. This tape was played at the opening of the conference in Cassino in May 2000. It is the last professional presentation by Professor Freudenstein. The transcript of the talk follows.

Bernard Roth
Stanford, CA

May, 2000

Dear Friends and Colleagues:

I would like to thank the organizers of this "International Symposium on the History of Machines and Mechanisms" for honoring me by extending this invitation to speak on my personal experiences in the field. I am sorry that I cannot be with you today, but I hope that I can convey—via this video—some of the progress that has been made in the theory of machines and mechanisms in the 20th century.

I cannot remember when I was not interested in machines and mechanisms. As a young boy of ten, who had just fled to England from Nazi Germany, I recall being fascinated in a London movie house by the Charlie Chaplin film, *Modern Times*. It was a devastating satire on industrial life and one scene, in particular, captivated my mind. It showed Charlie, a hapless factory worker, being sucked into the mechanism of a huge machine and being moved about in a prone position by enormous turning wheels. For weeks after that movie, I dreamed about Charlie moving around in that machine.

Several years would pass before that little boy, now a teenager, would arrive in the United States. I, the teenager, joined the American army when I reached the age of 18 and was discharged at the end of the war. With the assistance of the GI Bill, I then completed my education, earning an MS from Harvard in 1948 and a Ph.D. from Columbia in 1954. Both degrees were in Mechanical Engineering.

Before continuing, I believe that a short review of the development of "kinematics" during the 19th and early 20th centuries is in order. In 1834, the noted French scientist, Ampère, coined the term, kinematics. He used the term to designate the mathematical investigation of the motions that take place in mechanisms and machines and the investigation of the means for creating these motions. In Ampère's day, kinematics entailed, primarily, a description of particular machines and mechanisms with some analysis of their motions.

About 1860, scientists became intrigued by the search for a mechanical means of generating an exact straight line using pivoted linkwork. In 1864, Peaucellier's "cell" achieved this goal, but the subject continued to spur further developments in several countries. Cayley, Roberts, Burmester, Reuleaux, Mueller, Rodenberg, Gruebler, and Chebychev were among the outstanding international researchers.

The British analyzed the "geometrical and analytical" properties of the coupler curves, and they introduced velocity and acceleration polygons. They described mechanical elements such as cams, gears, links, and their proportions. They primarily used graphical methods to determine velocities and accelerations of points on these elements.

In Germany, Burmester used "projective geometry" to develop methods for the approximate generation of a straight line.

Proceeding from the same straight-line problem, Chebychev, in Russia, created the theory of polynomials deviating least from an arbitrary function.

Several decades later, in the 1920s, the "geometrical school" in Germany extended Burmester's ideas and began to formulate, for the first time, the concept of "kinematic synthesis." In contrast to kinematic analysis, which determines the motion characteristics of a given mechanism, kinematic synthesis proceeds from the given motion requirements to the determination of the type and proportions of an appropriate mechanism.

In 1944, Blokh introduced complex-number methods in kinematic synthesis using matrix algebra. In 1948, Dimentberg introduced the dual-number in the study of spatial motions. At about this time I began to think about applying for a Ph.D. I was working at the American Optical Company in Buffalo, NY, but the wheels were still turning in my head. I spent most of my free time searching out bookstores which had foreign texts on the mathematical development of kinematic ideas. I even learned a little Russian so that I could pour over the works of the Russian "greats." I still treasure this early library that I collected so painstakingly.

In 1950, I entered Columbia as a doctoral student. However, I had a very difficult time finding a doctoral advisor. Most of the mechanical engineers at that time understood very little about the theory of kinematics, and they were not impressed by my esoteric interests. I was very fortunate that a physics professor, teaching in the engineering department at the time, was willing to guide my work. He admitted to me that he really did not understand what I was proposing to do, but he had faith in me. This gentleman's name was Professor H. Dean Baker, and I shall never cease being grateful for his confidence in me.

My dissertation was published in 1954, and two papers were quickly printed in the Transactions of the ASME of April 1954 and August 1955. They were called "An Analytical Approach to the Design of Four-Link Mechanisms" and "Approximate Synthesis of Four-Bar Linkages." At this stage another problem arose. There were few people in the United States who were able to discuss and evaluate my work. A stroke of good fortune appeared in the form of another scientist. His name was A. E. Richard de Jonge, and he was a mechanical engineer for the Reeves Instrument Corporation in New York City. He had written a paper for the ASME in 1942 in which he drew attention to the very neglected study of kinematics and mechanisms in America. Mr. de Jonge agreed to critique my papers. In his discussion he explained that while Germany and Russia had done fundamental work in kinematics, practically no published work in kinematics existed in America. He was therefore delighted to find a paper on the subject written by a Junior Member of the Society. He stated that the papers he was reviewing treated four-bar linkages in an analytical and completely new way which allowed one to obtain basic values of four-bar mechanisms in a relatively simple way by calculation. The method gave the necessary accuracy required in computer work and military work. Mr. de Jonge sensed the coming explosion in the use of the computer in mechanical design. He wrote, "The greatest benefit of the use of the author's method is obtained when computing machines can be utilized." He also stated that the author's work went further than either the Russians or the Germans—and therefore should arouse great interest both in America and abroad and should have great practical consequences.

I continued to work throughout the next several decades, when the computer transformed the way we do engineering. I recall the great excitement that surrounded the development of DAMN (Dynamic Analysis of Mechanical Networks), an early engineering design program for computers, which was created by Milt Chace at the University of Michigan. It was my early graduate students who first disseminated the kinematics that they learned at Columbia. My earliest coauthors were these same graduate students: the late George Sandor, Bernie Roth, Andy Yang, Lee Dobrjansky, and R. E. Phillips.

In the early 1960s I met the outstanding mathematician, Eric Primrose, at a conference in England. We formed a very productive partnership. I would think up mechanical problems for which only Eric could provide the mathematical skills needed to work out the solutions. I am still grateful for his help. I can think of one visitor from abroad in the late 1950s whose meeting with me left an indelible impression. It was only a few years after the publication of my work that the renowned Russian scientist, Artobolevskii, came on a visit to America and stopped at Columbia to meet with me, a young assistant professor.

As I look back on my career, I realize that my timing was perfect. The computer age was incubating just about the time that I was incubating kinematic theory that would be utilized in the computer age. But that occurred in the 20th century. The 21st century is a blank page on which each of you at this conference can stamp your own genius in yet undreamed of ways. The possibilities are boundless. Good luck to all of you.

Ferdinand Freudenstein
New York, NY