TED B. BELYTSCHKO

1943–2014

Elected in 1992

"For development of nonlinear finite element methods and their applications to large-scale simulation."

BY JAN D. ACHENBACH AND WING KAM LIU

TED BOHDAN BELYTSCHKO, a mechanical engineering professor at Northwestern University for more than three decades and a pioneer in the art of computational mechanics, died September 15, 2014, at age 71.

Ted was born Bohdan Belytschko in the town of Proskurov in western Ukraine on January 13, 1943. World War II was raging and in February 1944 his parents, Stephan and Maria Belytschko, were forced to flee westward ahead of the rapidly advancing Soviet Army. They left precipitously with only their 13-month-old son, a little food, and a few photos. They were very fortunate to board the last train from Poland to Berlin before the railroad tracks were bombed. The family continued westward in Germany, reaching the Rhine Valley and eventually settling in the town of Krefeld where they waited out the end of the war. It was there that the first name Bohdan was deemed "too foreign" by the German authorities and Bohdan was rechristened Theodore.

Ted's father was concerned about the future geopolitical uncertainties of living in a divided Germany, and immediately began to apply for permission to emigrate under the Displaced Persons Act. This was a challenging and competitive process, and one of the requirements for receiving permission to enter the United States was a sponsor who could

confirm that applicants had a specific destination and would have a place to stay. Stephan and Maria made contact with a Professor Mikhailenko who lived in Chicago and who agreed to fill this role.

After numerous delays and frustrations, the family arrived in Chicago late in 1951. The Belytschkos were always profoundly grateful for the assistance "the Professor" provided as they adjusted to a totally new environment, not knowing English and with few marketable skills or financial resources. The respect and admiration voiced by his parents for "the Professor" over the years undoubtedly influenced Ted's later interest in the world of academia.

This was a difficult time, but Ted's parents found work anywhere they could and gradually achieved stability and a degree of prosperity. With the facility of the very young, Ted learned English quickly and one of his teachers in the local public school suggested that he might benefit from a different learning environment. He made some suggestions about private schools in the city, and Ted was eventually granted a scholarship at the Francis Parker School. This required a very long daily bus journey from the working-class neighborhood where he lived, but the school's academically nurturing culture provided him with a glimpse into the possibilities open to someone with ability and ambition.

By the end of middle school at Parker, Ted had developed a clear interest in mathematics and science, and he transferred to Lane Technical High School, a magnet school before the term existed, in the Chicago public school system. He graduated at the top of his class and entered Illinois Institute of Technology in Chicago on a full scholarship. Two things happened at IIT: he met his future wife Gail and Professor Philip Hodge.

IIT had a mechanics group that was very highly regarded and Ted was drawn to the field not only because of his growing interest in computational mechanics, but also because of the teaching skills and gentlemanly demeanor of Professor Hodge. With Hodge as his advisor Ted entered the graduate program in 1965 and received his PhD in 1968. He and Gail

married in 1967 and were blessed with three children, Peter, Nicole, and Justine.

Ted taught at the University of Illinois at Chicago Circle until 1977, when he accepted a position at Northwestern University in Evanston, Illinois. In his remarkable career at Northwestern Ted excelled in his field and became one of the most accomplished computational mechanicians in the world. He made major innovative and fundamental contributions to solid mechanics, and especially to computational mechanics, where his pioneering research gave the field the status it enjoys today.

His contributions were multifaceted and truly visionary, and have inspired many new directions of research. For example, he developed nonlinear explicit finite element methods and multiscale and mesh-free methods, which have enabled the solution of previously intractable problems such as simulations of automotive crashes and dynamic crack growth. Other major accomplishments among his numerous innovations include methods of time integration, solid-fluid interactions, element-free Galerkin methods, the extended finite element method (X-FEM), and multiscale modeling such as bridging domain methods.

Among his important contributions to computational engineering, his three major papers on mesh-free methods have been cited more than 4,200 times and his six major papers on X-FEM have been cited about 4,000 times. He is one of the most highly cited authors in engineering science: 30,417 citations and an h-index of 91 (ISI Web of Science Citation Report, January 2014). His books on the finite element method are extremely popular with students, engineers, and professors.

His work also had an important impact on computational methods in industry. All commercial finite element software for crashworthiness analysis now uses the Belytschko-Tsai element. His method of reduced integration with hourglass control removes locking and significantly increases speed, making numerical simulations of crashworthiness possible. These inventions have been adopted for the commercial finite element software ABAQUS-EXPLICIT and LS-DYNA, and by

the public domain code DYNA. His development of the pinball and related sorting bucket algorithms is used in modeling of the deployment of airbags from their fully folded configuration. These simulations have allowed companies to confidently design products using computers, reducing costs and the time required to move new designs quickly into production.

Ted received numerous honors for his research. He was a member of the National Academies of Sciences and Engineering, and a fellow of the American Academy of Arts and Sciences. From the Association for Computational Mechanics he received the Computational Structural Mechanics Award in 1997 (renamed the Belytschko Medal in 2013) and John von Neumann Award in 2001; he was also selected for ASCE's Theodore von Karman Medal in 1999, the ASME Timoshenko Medal in 2001, the Gauss-Newton Medal from the International Association for Computational Mechanics in 2002, and the William Prager Medal from the Society of Engineering Science in 2011.

He provided invaluable leadership to the mechanical engineering community. He chaired the ASME Applied Mechanics Division Executive Committee (1990–1991) and the Mechanical Engineering Department at Northwestern University (1997–2002); authored popular textbooks on computational mechanics; and served as editor in chief of the *International Journal for Numerical Methods in Engineering*, a major journal in computational science and engineering.

Professor Belytschko's legacy will live on in the work of the many students, postdocs, and researchers whose lives he influenced.

He was a true world leader in computational mechanics.