MITMECHE

MECHANICAL ENGINEERING COLLOQUIUM SERIES 2014-2015

Den Hartog Lecture in Mechanics

Modeling and Simulation of Highly Nonlinear Fluid-Structure Interaction Problems

Charbel Farhat

Vivian Church Hoff Professor of Aircraft Structures
Departments of Aeronautics and Astronautics and Mechanical Engineering
Stanford University

on Friday, April 10th at 4:00pm in 3-270

Fluid-structure interactions are among the most important considerations when designing complex engineering systems such as aircraft, turbine blades, formula 1 cars, and underwater vessels, to name only a few. They are also important for the analysis of aneurysms in large arteries and artificial heart valves. They can significantly affect performance and/or structural integrity. Many such interactions are highly nonlinear. Consequently, their numerical prediction is fraught with computational challenges. For example, the implosive collapse of a submerged, gas-filled structure and its subsequent effect on the structural integrity of a near-by system is a transient, high-speed, multi-phase fluid-structure interaction problem characterized by ultrahigh compressions, shock waves, large structural deformations, self-contact, and possibly the initiation and propagation of cracks. Bio-inspired micro air vehicles operate in the lower Reynolds number regime and tend to have light weight flexible flapping wings. Their unsteady and turbulent aerodynamics are closely linked to their structural dynamics which features large motions and deformations, and their flight characteristics are affected by environmental factors such as wind gust. Formula 1 cars and fighter aircraft operate in the higher Reynolds number regime. They perform aggressive high-G maneuvers characterized by high angles of attack, and turbulent viscous flows driven by large structural motions. To this effect, this lecture will present a robust and unified computational framework for the numerical simulation of highly nonlinear fluid-structure interaction problems, including those characterized by multi-material domains. It will discuss its mathematical properties, and highlight its potential with validated simulations of material failure driven by multi-phase fluid-structure interaction, underbody blast events, flexible flapping wings, aeroelastic tailoring of Formula 1 cars, and vertical tail buffeting of fighter jets at high angles of attack.

Jacob Pieter Den Hartog (1901-1989) was an internationally famous vibration and dynamics expert and a consummate teacher who enriched generations of students with his verve, wit, and captivating physical insight. Jaapie, as he was called by his friends, was born and raised in the Dutch East Indies, went to school in Holland, and graduated from TU Delft in electrical engineering. In 1924, he emigrated to America and joined the Westinghouse Company. There he met Timoshenko, who converted him into a mechanical engineer. In parallel, he obtained his PhD at the University of Pittsburgh. After a postdoctoral sabbatical with Ludwig Prandtl, he started his academic career in Harvard in 1932. Here, he wrote his magnum opus "Mechanical Vibrations", which remains the classic textbook of vibrations to this day. He served in the US Navy during WWII and joined Mechanical Engineering at MIT in 1945, where he wrote three more textbooks and was Department Head from 1954-58. He was an accomplished educator and sought-after consultant till he retired from MIT in 1967. In 1972, ASME awarded him with the Timoshenko Medal, which was followed by several honors including the James Watt Medal from the British Institution of Mechanical Engineers, NAE Founders Award, and the Order of the Rising Sun from the Emperor of Japan. In 1987, ASME established the J. P. Den Hartog Award for "sustained meritorious contributions to vibration engineering". The Den Hartog Prize for Excellence in Teaching and the Den Hartog Lecture in Mechanics established by the Department of Mechanical Engineering at MIT continue to remind us of his remarkable legacy.

Refreshments will be served before the seminar.
Please contact Tony Pulsone at pulsone@mit.edu with any questions.

MITMECHE

http://mechecolloquium.scripts.mit.edu/home/