



J. R. DeW. Hartley

JACOB PIETER DEN HARTOG

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ALTHOUGH I HAD STUDIED his book *Mechanical Vibrations* in 1940 when I was an undergraduate at Stevens, I did not meet Professor Den Hartog until the fall of 1946 when I joined the faculty of the mechanical engineering department at MIT. Den Hartog had himself come to MIT only a year earlier after serving in the navy during the war. Twenty years my senior and already world famous, he was both an inspiring role model and a gracious mentor. He was internationally famous as a vibration consultant with an uncanny ability to identify and explain the cause of a mysterious vibration. But, above all, Den Hartog was a consummate teacher. He could hold the attention of a single colleague or a class of a hundred students as he explained a particular mechanism and wrapped his audience in the sheer fun of imagining how it would move and why. He taught dynamics by creating vivid images of particular cases that dramatized generic concepts. Generations of students were enriched by his verve, wit, and captivating physical insight.

Jacob P. Den Hartog was born in Ambarawa on the island of Java in the Dutch East Indies on July 23, 1901. His father, Maarten, had been a school teacher in Amsterdam until he was dismissed because of radical activity. Maarten had been

an outspoken supporter of Alfred Dreyfus in the early phases of that famous affair when the popular view was strongly against Dreyfus. The family was forced to go to the Indies, and Maarten taught school in the colonial system in Ambarawa, Makassar, and Batavia. Young "Jaap" grew up speaking Dutch and Malay. He attended elementary school and took violin lessons. When it was time for Jaap to enter high school, it was decided that he, his two younger sisters, Wilhelmina and Clara, and his mother, Elizabeth, would return to Amsterdam, while Maarten would remain in Java. Because Holland was a neutral country during the First World War, their ship could sail, brightly lit, without interference from submarines, although it was necessary in 1916 to bypass the Suez Canal and sail down around the southern tip of Africa and up around Iceland to reach Holland.

The following eight years were difficult for the Den Hartog family. Maarten, the father, died in Java soon after the family returned to Holland, and his widow was left with three children to support. Jaap was such an outstanding high school student that some of his relatives undertook to pay his expenses at the Technical University of Delft. Entering Delft in 1919, young Den Hartog decided to become an electrical engineer after seeing a dramatic physics demonstration in which a bolt of lightning jumped from one charged sphere to another. He was a good student, but because of his limited financial situation he was unable to participate in sports or social activities. He compensated for this by developing a strong prejudice against the rich. Economic conditions in Holland were sufficiently bad in 1924 when he graduated that even the best Delft students could not be sure of finding a job. For some reason, Den Hartog did not try very hard. He made only two applications, and when he was rejected, he impulsively decided to leave Holland to seek his fortune in the United States.

Arriving in New York without connections and essentially penniless, Den Hartog took to America with great enthusiasm. He worked briefly at a sequence of temporary jobs until he learned that Westinghouse was hiring electrical engineers in Pittsburgh. Luckily he was accepted by Westinghouse just in time to be placed in an in-house training course for new engineers. Among the lecturers was Stephen P. Timoshenko, an emigré Russian professor of mechanics who had been hired by the Westinghouse Research Laboratories the previous year. Timoshenko was impressed by the eager young Dutchman. None of the American engineers had even heard of a Bessel function. When the training course was completed, Timoshenko requested that Den Hartog be assigned to the mechanics section of the research laboratories to work as his assistant. It was here that Den Hartog served his real professional apprenticeship. In the next three years Timoshenko converted the young electrical engineer into a mechanical engineer by assigning him a wide variety of vibration problems across the whole spectrum of Westinghouse products: electric motors and generators, steam turbines, hydropower turbines, railroad electrification, etc. While working at the research laboratories during the day, Den Hartog studied mathematics in the evenings at the University of Pittsburgh. In 1926, after receiving a steady salary for nearly two years, he considered his prospects sufficiently good that he proposed to his childhood sweetheart, Elisabeth F. Stolker. They decided to have the wedding in Amsterdam during his summer vacation and to consider the ocean voyage back to America as their honeymoon. The young couple called each other by their Dutch diminutives, Jaapie and Beppie, as did most of their friends throughout their lives. They set up housekeeping in Pittsburgh and bought a piano for Beppie, who was an accomplished pianist. As enthusiastic emigrés, they made a pact

to always speak English to one another. A year later their first son Maarten was born.

Technically, Westinghouse was an exciting place to be during the twenties. This was a period of industrial growth and expansion. Challenging engineering problems were being successfully solved in innovative ways by highly talented individuals. In the mechanics section the most influential person was Timoshenko. With his powerful personality he was an inspirational leader for the young men in the division. He made them feel they were capable of great accomplishments and encouraged them to publish their results as technical papers. The five years that Timoshenko spent at Westinghouse have been called its "golden era of mechanics" in which rational analysis blossomed and took precedence over empirical methods. By the time Timoshenko left to join the faculty at the University of Michigan, the mechanics sections had grown to include J. M. Lessells, G. B. Karelitz, R. E. Peterson, J. Ormondroyd, A. M. Wahl, and A. Nadai, in addition to Den Hartog. They also worked closely with outstanding engineers in other departments, such as C. R. Soderberg in the generator department and L. S. Jacobsen in the motor department.

The theory of vibrations had been assembled in volume 1 of Lord Rayleigh's *Theory of Sound* in 1877 and subsequently been applied to technical problems by European engineering professors, but in the twenties it was still terra incognita to most American engineers. Den Hartog was forced to acquire this expertise in a hurry under the supervision of Timoshenko. Because of his strong mathematical background Den Hartog had little difficulty. Furthermore, having to learn the theory in the context of a sequence of urgent real problems gave him a unique practical approach to the subject, which illuminates his famous text, *Mechanical Vibrations*. Early on he exhibited a flair for the dramatic.

One of his first cases involved the shaft of a motor-generator set that was continuously breaking. Timoshenko recognized the fracture as due to torsional fatigue and suggested that Den Hartog calculate the torsional resonance. It turned out that the torsional critical speed was exactly at the operating speed. Furthermore, only a slight detuning was required to alleviate the situation. Although the detuning could be accomplished equally well by either stiffening or softening the shaft, Den Hartog boldly recommended that the diameter of the shaft be reduced by one-sixteenth of an inch. When this unlikely cure completely solved the problem of broken shafts, his reputation as a vibration expert was launched.

While at Westinghouse, Timoshenko was one of the activists pressing for the establishment of a separate Applied Mechanics Division within the American Society of Mechanical Engineers (ASME). When the division was finally started in 1927, Den Hartog plunged into its activities with great energy. In the *Transactions* for that first year are his first three published papers. It should be remembered that this occurred at the same time that he was working on his doctoral dissertation. When he received his Ph.D. degree from the University of Pittsburgh in 1929, he had published a total of eight papers on technical problems he had solved at Westinghouse. His dissertation, "Nonlinear Vibration with Coulomb Damping," provided material for three more publications. In 1930 he received another document to which he had long looked forward: his certificate of naturalization as a citizen of the United States of America.

The mechanics section continued to grow. A new addition in 1929 was O. G. Tietjens, who had been an assistant to Professor Ludwig Prandtl in Göttingen. Tietjens had published a two-volume book in Germany based on Prandtl's lectures. Den Hartog encouraged him to have these trans-

lated into English and published in America and undertook the translation of the second volume, *Applied Hydro- and Aero-Mechanics*, himself. In 1930 there was a major reorganization of the mechanics section. The section became a department divided into two sections: dynamics and materials. J. M. Lessells became manager of the mechanics department, while the dynamics section was headed by Den Hartog and the materials section by R. E. Peterson, who later became department manager when Lessells was transferred to Philadelphia. At this time, management did not have much appeal for Den Hartog. He arranged to spend the following year, his sabbatical year at Westinghouse, as a postdoctoral student in the laboratory of Professor Prandtl. Jaapie and Beppie, with young Maarten, enjoyed this year in Göttingen immensely. For Jaapie it was an unexcelled opportunity to meet the engineering research leaders of Europe. This was to stand him in good stead fourteen years later. Soon after returning to Pittsburgh, he was offered an appointment as assistant professor of mechanical engineering at Harvard University. He had already done some lecturing in the Westinghouse training courses for new engineers, and he jumped at the chance to try teaching as a full-time occupation.

In September 1932 Den Hartog arrived at Harvard and started his academic career. Full of enthusiasm, he poured his energies into his vibrations course, getting an extensive collection of demonstration models made and starting to write his famous text *Mechanical Vibrations*. Although only thirty-one years old, he already was widely known as a vibration expert. Professor E. S. Taylor at neighboring MIT told me how he and other young MIT faculty used to regularly ride the trolley over to Harvard to sit in on Den Hartog's lectures.

During the decade at Harvard, Den Hartog was engaged

in a variety of professional activities. Perhaps the most important achievement was the publication of *Mechanical Vibrations* in 1934, with a second edition in 1940. This book remains *the* classic vibration text. The early chapters follow the grand outline of Rayleigh but have a less mathematical, more appealing, practically motivated style. What distinguishes it from any other text, before or since, are the chapters on vibrations of real machines (reciprocating engines, rotating machinery) and the simplified physical explanations for an extensive catalog of self-excited vibration phenomena. During these years Den Hartog continued his active involvement with the Applied Mechanics Division of ASME. When the *Journal of Applied Mechanics* began separate publication in 1933, it contained at least one of his contributions each year for the first seven years. He served as division chairman in 1940 and 1941. Another important involvement was with the International Congresses of Applied Mechanics, which renewed and extended his relations with European scientists. He presented a paper at the fourth congress held in Cambridge, England, in 1934 and took an active part in hosting the fifth congress, held in Cambridge, Massachusetts, in 1938. He also served as coeditor of the proceedings of the fifth congress.

While at the University of Michigan, Timoshenko organized an annual special summer school for teachers of mechanics, which had an important influence on mechanics education in America. Den Hartog acted as a guest lecturer for several summers in this program while he was at Harvard. It was also during this period that he began to take on consulting jobs. His principal clients were Hamilton Standard, an aircraft propeller manufacturer, and two builders of Mississippi tugboats that had torsional vibration problems in their diesel engine drives.

The decade at Harvard also saw many changes in the

family life of the Den Hartogs. They bought a house in Wellesley. Their second son, named Stephen Ludwig, in honor of Timoshenko and Prandtl, respectively, was born in 1933. A weekly ritual was the musical evening when Jaapie, joined by two fellow amateurs plus a professional cellist, played string quartets. In 1938 the Den Hartogs bought a small island in Lake Winnepesaukee, some 75 miles north of Boston, and built a cabin from the timber provided by the big hurricane that year. The island was to play an important part in their lives after the war.

In 1939 Den Hartog volunteered for a commission in the U.S. Naval Reserve. This may seem like a strange thing for a successful academic to do in mid-career. I believe he had two major reasons. First, he had come to the conclusion that war was inevitable and he wanted to position himself advantageously for that outcome. Second, he had begun to chafe at the low esteem with which engineering seemed to be regarded by most of the Harvard administration. His own position was safe (tenure had come with his promotion to associate professor in 1936), but he was irked by the policy decision to move away from engineering toward applied science. At any rate, he was given a commission as a lieutenant commander on inactive duty, which he held for two years until June of 1941 when he was called up for active duty. A year later he resigned from Harvard.

The four navy years proved to be an exciting entr'acte in Den Hartog's academic career. Initially, he was assigned to the Taylor Model Basin in Bethesda, Maryland, near Washington, D.C. He immediately contracted to have a house built in the neighborhood, put a "For Rent" sign on the house in Wellesley, and moved the family down to Washington. After Pearl Harbor he was transferred to the Bureau of Ships in Washington. The next three years were full of hard work but were very stimulating from a professional point of

view. The navy was building ships as fast as it could, and they all had potential vibration problems, from windshield wipers on P.T. boats to propeller shafts on cruisers. Den Hartog shuttled back and forth from design conferences on one ship to sea trials on another. He was involved in most of the interesting vibration problems, and he had the opportunity to interact with many of the country's leading engineers. In February 1943 he was promoted to the rank of commander. Later that year he was approached by MIT administrators and it was decided that he would join their faculty "after the war."

In August of 1944 it began to be clear that the Allies were prevailing over the Nazis in Europe. The navy decided to send a special technical mission to Europe. This group of some forty officers and sixty enlisted men was to follow the advancing Allied forces with the aim of debriefing enemy technicians and capturing interesting technical equipment. Commander Den Hartog was an ideal choice for this mission. He spoke Dutch, Flemish, German, and French and knew many European scientists personally. In his wartime diary Den Hartog called this final year of the war "the most interesting year of my life."

The technical mission arrived in France shortly after its liberation and set up headquarters in Paris. For most of the year normal operations involved trips in teams of two or three officers to target locations. Typically, the information and equipment could be obtained in a few days, and the team returned to Paris to write up its reports and plan the next trip. Travel close to the front lines was always difficult and involved many frustrations with interservice red tape. Den Hartog's targets in the winter of 1944-45 were in Belgium, France, and England. In the spring his targets were in a sequence of German cities, including Göttingen, Nürnberg, and Buchenwald as the Nazis retreated. When

the Germans surrendered in Holland and Denmark, he immediately went to Holland and was in Amsterdam on V-E day. The technical mission continued in high gear for an additional three or four months. In Denmark Den Hartog stumbled on a number of midget submarines still in shipping containers and was able to arrange to have five of them, plus five trained German operators, sent back to the States for careful appraisal of their capabilities.

The technical mission worked hard for a year. It also played hard. Evenings back in Paris often involved dates, dinner and dancing, and theaters or concerts. American officers with easy access to cigarettes and nylons were the privileged rich of wartime Paris. Den Hartog was an enthusiastic participant in these extracurricular activities. He organized a string quartet and rented instruments for them to play. He had connections with well-placed French families who were only too happy to be invited to the officers' dining room. He also enjoyed striking up friendships from chance encounters. With his command of languages he was often the one who provided dates for his colleagues. In his diary he observes that, "The upper class and the lower class know how to enjoy themselves, but Lord deliver me from the up-tight middle class." When he and two of his colleagues were promoted to captain, he arranged for a dinner party of sixty men and thirty ladies, with corsages for the ladies, 100 bottles of champagne, a dance band, and twenty bottles of cognac.

In September 1945 Captain Den Hartog was deactivated, and Professor Den Hartog took up his new post as professor of mechanical engineering at MIT. After the excitement of the previous year, it took a while to get back into the academic groove. He began by teaching one class and working on the third edition of *Mechanical Vibrations*. Gradually, Den Hartog began to expand his activities. He took on the task

of acting as graduate student registration officer for the department and recommenced supervising doctoral students. He also began to play in the violin section of the MIT orchestra. The buildings on the island in Lake Winnepesaukee were expanded to facilitate entertaining, and an isolated study cabin was built with a huge desk looking out on the water. It was here that Den Hartog wrote his textbooks on *Mechanics* (1948), *Strength of Materials* (1949), and *Advanced Strength of Materials* (1952). His consulting practice began to grow. Typically, a newly built structure or machine would be found to be inexplicably vibrating. Professor Den Hartog would be telephoned and would travel to the site by overnight train. He would observe the phenomenon intently and ask many questions. In his mind an image of the underlying phenomenon would develop, along with a diagnosis of the most probable cause. He would then share his surgical insight with the client, with clarity and humor. In many cases his initial insight was sufficient to provide the basis for a satisfactory solution. In obstinate cases additional tests would be recommended to pinpoint the difficulty. A great many of his clients were satisfied with the results after only one or two days of professional service. An exception was Exxon, which kept him on a retainer for thirty-four years and regularly sought his advice over a wide range of problems.

In the fifties Den Hartog was at his peak as an educator. He had become an entertaining raconteur with a large store of real case histories that he used to illustrate fundamental concepts. For the graduate students in mechanical engineering, his lectures were the high point of their MIT education. Following in the footsteps of his mentor Timoshenko, he organized his own special summer courses in vibration for engineers in industry. He and Beppie often entertained students and visiting academics on their island. For many

foreign scientists, their most vivid memory of America is of being enthusiastically bundled into a car, driven up to New Hampshire, seated in a canoe, and paddled across the lake to spend an idyllic weekend on the island. In the early fifties the Den Hartog's son Maarten, now an architect, designed them a spacious house in Concord, ideal for entertaining. The house, only 18 miles from MIT, was heavily used for that purpose, especially during the years 1954-58 when Den Hartog served as head of the Department of Mechanical Engineering. It was in this period that he sandwiched a sabbatical term in Japan as a Fulbright lecturer in 1955 and went to England in 1957 to give the Thomas Hawksley Lecture, the first American to be so honored. He also made a final improvement of *Mechanical Vibrations*, publishing the fourth edition in 1956. By this time the book had become world famous. In all there were fifteen foreign editions published in eleven languages.

When Den Hartog returned to teaching in 1958, the jet airplane had arrived and was making travel more convenient, especially for lecture tours and consulting visits. He lectured widely in America and abroad, including the Soviet Union in 1960 and 1961. As he began to approach retirement, he was honored with an increasing stream of awards. The Design Division of ASME dedicated the proceedings of its first vibration conference as a Festschrift to Den Hartog on the occasion of his retirement at age sixty-five in 1967. He continued part-time lecturing and consulting for an additional five years but had to cut back on some activities. Arthritis in his fingers made it impossible to play the violin. In 1972 the Applied Mechanics Division of ASME awarded him the Timoshenko Medal, established in honor of his early mentor. The ceremony took place just a few months after Timoshenko's death at the age of ninety-three.

In the following decade there was a gradual slowdown in

Den Hartog's consulting activities and occasional lectures as the grip of arthritis strengthened throughout his body. The year that he was eighty (1981-82) was the final year before he became totally bedridden. It was, however, a memorable year. On his birthday MIT's Department of Mechanical Engineering established the Den Hartog Prize for "excellence in teaching." A few months later the British Institution of Mechanical Engineers awarded him the prestigious James Watt Medal. Then the National Academy of Engineering awarded him its top honor, the Founders Award. Finally, the following spring he received the Order of the Rising Sun, signed by the Emperor of Japan.

At this point his arthritis-ravaged body finally surrendered, imprisoning his active spirit in a skeleton he could not move. His last major project, which he directed from his bed, was the sale of the Concord house and the purchase of a condominium for Beppie next door to a nursing home in Hanover, New Hampshire. The plan was sound. Jaapie was installed in the nursing home. Beppie had her own apartment a few steps away, and their son Stephen, who worked in Hanover, could conveniently drop by to check on his parents. And so it worked until Easter day 1985, when Beppie passed away peacefully in her sleep.

Jaapie lived another four years unable to move himself, unable to read or write. He spent his time listening to music, mostly string quartets, and the Public Broadcasting news programs. He never complained. He could look back on a very full life: the excitements of emigration and the wartime adventures, the challenges of strange new consulting problems, and the solid accomplishments of a beloved teacher. His major contribution was the book *Mechanical Vibrations*. There were also several valuable contributions to the theory of vibrations in his research papers. Of particular importance are his extensions to systems with damping

of the theory of dynamic vibration absorbers (1928,2) and of the Holzer method for torsional vibration (1946). He was the first to obtain solutions for vibratory systems with Coulomb damping (1931). He was also the first to give a quantitative explanation for the phenomenon of galloping of ice-laden transmission lines (1932,2). But most of all he could look back on the fun he had teaching generations of students who went on to make successful careers of their own.

In his twilight years Jaapie was not forgotten. Many of his students and colleagues made the pilgrimage to Hanover to visit him. He enjoyed these visits. His mind remained clear, his memory excellent. He would retell the old stories, but he also retained his curiosity about the present and the future. In 1987 the Design Division of ASME announced the establishment of the J. P. Den Hartog Award for "sustained meritorious contributions to vibration engineering" at its eleventh vibration conference. The first recipient of the award was Den Hartog himself. This was twenty years after the first vibration conference had been dedicated to him. When the medal was delivered to him he was pleased to think that "his boys still remembered him." Those of us who were fortunate enough to have known him in his active days will always remember his uncanny physical insight and the energetic enthusiasm and sparkling wit with which he made it all seem so clear.

I WISH TO THANK Stephen L. Den Hartog for his gracious help in giving me access to his father's files and wartime diaries and for supplying details of the family history.

HONORS AND DISTINCTIONS

PROFESSIONAL SOCIETIES

American Society of Mechanical Engineers
American Consulting Engineers Council
American Society of Engineering Education
Institute of Aeronautical Sciences
Sigma Xi
Society of Naval Architects and Marine Engineers
Tau Beta Pi

HONORS AND AWARDS

American Academy of Arts and Sciences, Fellow
American Society of Mechanical Engineers, Honorary member
Japan Society of Mechanical Engineers, Honorary member
National Academy of Sciences, Member
National Academy of Engineering, Member
Royal Dutch Academy of Arts and Sciences, Foreign member
Charles Russ Richards Medal, Worcester Reed Warner Medal,
Timoshenko Medal, ASME Medal, and the Jacob Pieter Den
Hartog Medal of the American Society of Mechanical
Engineers
Founders Award of the National Academy of Engineering
Lamme Medal of the American Society of Engineering Education
Order of the Rising Sun
Thomas Hawksley Lecture and the James Watt International Medal
of the Institution of Mechanical Engineers
Trente-Crede Medal of the Acoustical Society of America

HONORARY DEGREES

Carnegie Institute of Technology
Salford University
Technical University of Delft
University of Newcastle-Upon-Tyne
University of Ghent

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