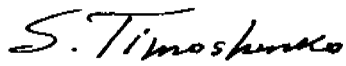

# STEPHEN P. TIMOSHENKO

*December 23, 1878–May 29, 1972*

BY C. RICHARD SODERBERG

THE MAJOR FACTS of the life of Stephen P. Timoshenko are by now well known. He was born as Stepen Prokofyevich Timoshenko* in the village of Shpotovka in the Ukraine on December 23, 1878. Stephen's father, born a serf, had been brought up in the home of a landowner, who later married Stephen's aunt. His father subsequently received an education as a land surveyor and practiced this profession until he himself became a landowner of some means.

Timoshenko's early life seems to have been a happy one, in pleasant rural surroundings. The concluding decades of the nineteenth century were a period of relative tranquility in Russia, and the educational ideals of the middle class were not much different from, and certainly not inferior to, those of their counterparts in Western Europe. He concluded his secondary education with a gold medal at the *technical realschule* † in Romny, near Kiev. His father had rented an

NOTE: The Academy would like to express its gratitude to Dr. J. P. Den Hartog for his help in the preparation of this memoir after the death of C. Richard Soderberg in 1979.

*The spelling of Russian names and terms follows that of E. H. Mansfield and D. H. Young, "Stephen P. Timoshenko," in: *Biographical Memoirs of Fellows of the Royal Society*, vol. 19 (London: The Royal Society, 1973), pp. 679–94.

†Professor Tichvinsky informs me that this designation was already used in Russia to indicate preparation for entry into technical universities. In most of Western

apartment there in which young Stephen and a friend lived, together with Stephen's grandmother. His outstanding subject appears to have been mathematics. His enjoyment in helping classmates with their studies anticipated his subsequent desire to become a teacher. Timoshenko had already developed an intuition for good teaching, but his early ambition was to become a railway engineer. His language studies were less successful, and his Russian had a strong Ukrainian accent, but he appears to have been well read in the Russian classics.

One of the principal objectives of the *technical realschule* was to prepare for the entrance examinations to institutions of higher learning. In 1896 Timoshenko took the examination to enter the Institute of Engineers of Ways of Communication at St. Petersburg, which he seems to have passed with honor.* The trip to St. Petersburg, on which he was accompanied by his mother, opened his eyes to the outside world and began his indefatigable habit of traveling and visiting cathedrals, harbors, bridges, and the like, which was to continue to the end of his life.

His five years (1896–1901) at the Institute of Ways of Communication were spent in intensive and single-minded studies in the sequence of subjects in engineering. But this period also marked the beginning of the end of the years of political tranquility in Russia, and soon there were many incidents of student unrest. Timoshenko always took the liberal view, but one gets the impression that he also regarded these incidents as obstacles to his own professional development.

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Europe distinction was made between the science-oriented *realschule* and the humanities-oriented *latinschule*. The *technical realschule*, which came later, was a "normal" school where science received greater emphasis than in a gymnasium.

* To play safe he also applied to the Institute of Civil Engineers, which gave easier examinations. The admission rate was twenty to thirty students from among one thousand who had taken entrance examinations, and only good students dared to take these exams.

He graduated in 1901; before this he had made two trips to Western Europe during vacation periods. These trips stimulated him greatly; they were the beginning of close associations with outstanding professionals, particularly in Germany.

His military service, which started in September 1901, after his second trip abroad, seems to have been a much more constructive experience than that in corresponding systems in most European nations at the time. He did not have to drop his professional contacts completely, and he actually started his career as a teacher at the Institute during this period.

Following his military service, in 1902, he married Alexandra Archangelskaya, a student in medical school and an acquaintance from his student days. At that time, he was serving in the Mechanics Laboratory of the Ways of Communication Institute, where, in addition to his duties in testing of materials, he also participated in supplementary lectures in mathematics given by Professors Stanevich and Bobylev, among others.

This noncompulsory program of studies seems to have been important: it brought him into contact with several young physicists, and he also began to attend the sessions of the Physical Society. It made him aware of an issue in engineering education that has remained important ever since. The engineers needed a much more mature background in science, particularly in mathematics, but the professional mathematicians of the period pursued very abstract lines of thought that often failed to attract the interest of the engineering students. The physicist Aleksey N. Krylov appears to have been one of the first to clarify this situation for Timoshenko. Later in his life, and at a more advanced stage, Felix Klein inspired him the same way. Timoshenko, meanwhile, developed his own utilitarian attitude toward mathematics.

In 1903 Timoshenko was made an instructor in the newly organized St. Petersburg Polytechnic Institute; the following years at this Institute mark the beginning of his creative scientific work. He spent the summers in Europe, mostly in Germany, where he received important inspiration from August Föppl in Munich, Ludwig Prandtl and Felix Klein at Göttingen, and others. In his autobiography,* Timoshenko occasionally criticized some of the lecture courses at the Institute in St. Petersburg, but he mentions several of the outstanding teachers, such as Prince Gagarin, the Director of the Institute, who gave English lessons using results in Love's Theory of Elasticity as exercises, and Viktor Kirpichev, who induced him to read G. Lamé, Bernhard Riemann, F. Grashof, and, perhaps most important, Lord Rayleigh's "Theory of Sound." Kirpichev's influence on Timoshenko was very important; through him he was introduced to the Castigliano theorem and the Rayleigh-Ritz method. These influences finally induced Timoshenko to become a teacher rather than a practicing engineer.

The school year 1904–1905 was much influenced by political turmoil in Russia—the disastrous Japanese War increased student demonstrations and general unrest. The Polytechnic Institute in St. Petersburg was closed, and Timoshenko decided to use the time studying under Prandtl at Göttingen. Prandtl, already a professor at twenty-nine, had contributed to Timoshenko's main subject of interest at the

*Stephen P. Timoshenko, *As I Remember* (New York: Van Nostrand, 1968). The original of this autobiography was written in Russian after Timoshenko's trip to Russia in 1958. It was published in Paris in 1963. The foreword to the Russian edition was written by Eugene A. Vetchorine, chairman of the Association of Graduates of St. Petersburg Polytechnic Institute. The translation into English was by Robert Addis under the guidance of Professors J. M. Gere and D. H. Young of Stanford University. The volume contains a complete listing of Timoshenko's publications as of March 1967. It also contains a list of Timoshenko's doctoral students in the United States.

time: the buckling of beams. Here Timoshenko made his first creative discovery in connection with the buckling of I-beams, where the torsion of rectangular elements of the section had to be taken into account. But by this time, Prandtl had left the field to concentrate on his epoch-making work in connection with boundary layers in fluid flow. It is remarkable, and to some degree characteristic of Timoshenko's single-minded devotion to his own studies, that he makes only a passing reference to this important event.

The stay in Göttingen was important in many other respects. Felix Klein had succeeded in expressing his conviction of the necessity for strong links between abstract and applied sciences. The School of Philosophy at Göttingen had already established an Institute of Applied Mathematics (Carl Runge), Applied Mechanics (Prandtl), and Electrical Engineering (Simon). The impressions from these developments patterned his attitude toward education in technology and contributed much to his future development as a teacher.

The situation in Russia continued to be characterized by much political unrest, and in the summer of 1906 Timoshenko resumed his studies at Göttingen, extending them to potential theory, thermodynamics, and other areas, while continuing his work on elastic stability and buckling. In the fall of 1906 he was appointed to the Chair of Strength of Materials at the Polytechnic Institute in Kiev. The return to his native Ukraine turned out to be an important part of his career and also influenced his future personal life. He was elected dean of the Division of Structural Engineering in 1909; he never ceased to regret the inevitable interference with his own work that this position brought. Political unrest again began to be felt, however, and his ideas of academic freedom now came under scrutiny. In 1911 this conflict led to his dismissal from the school, together with two other professors. Ten professors then resigned their positions in

the spirit of solidarity, so strong were their beliefs in the right of the cause.

These difficulties notwithstanding, his scientific work matured, particularly the ideas of strain energy and the Rayleigh-Ritz method in their application to buckling. In his own lectures, begun in 1907, he had gradually developed the technique of beginning a course with the simplest and most elementary concepts, gradually leading to more complicated and sophisticated methods of analysis. His first textbook appeared in 1911, a year that marked the beginning of a period of more than ten years of uncertainty, anxiety, and hardship. One bright event was his winning the Jourowski Medal in 1911, along with 2,500 gold rubles.*

In the fall of 1911, he went to St. Petersburg and succeeded in getting part-time teaching work, meanwhile continuing his writing. During the summer of 1912, he and his wife decided to use the gold rubles from the Jourowski Prize for a trip abroad. This journey was extended to England, where Timoshenko attended a mathematical congress in Cambridge. He met, for the first time, Lord Rayleigh, A. E. H. Love, Horace Lamb, and Levi Civita, among others. One of the lectures at the congress was given by the young representative from Göttingen, Theodor von Kármán. Timoshenko found himself hampered by lack of fluency in English, a lack he determined to remedy as soon as possible. He did not have a scientific discussion with Lord Rayleigh, chancellor of the University, except as part of the crowd at a reception in the University museum.

Returning to Russia in the fall of 1912, he resumed part-time teaching in several schools in St. Petersburg. He was also invited to teach at the Ways of Communication Institute,

*This illustrates again the courage and solidarity of the Russian men of science, who awarded their top prize to a man dismissed from his job.

where he took over some of the work in theoretical mechanics from Professor Krylov, who had retired. But events overtook him before he really got started on this program; he did not resume this work until he had emigrated to the United States. During this period he also worked on applications of elastic stability to ship bulkheads as a consultant to the Naval Ministry in St. Petersburg. These activities improved his financial position, but the living conditions in St. Petersburg were difficult, and his health was impaired. During this period he happened to meet Paul Ehrenfest, with whom he formed a lasting friendship. Ehrenfest had come from Germany to Russia in the hope that academic freedom there would offer him better opportunities. He was not successful in establishing himself in Russia, but the two met frequently; Ehrenfest would then enlarge upon the current ideas abroad in physics—relativity and quantum physics—new to Timoshenko at the time.

Timoshenko's period of disgrace with the authorities ended in 1913, when he was confirmed in the position of professor at the Ways of Communication Institute, an appointment later extended to include teaching at the Electrical Engineering Institute of the Polytechnic Institute. In the autumn of 1913 he was asked to reorganize the teaching of strength of materials, succeeding Professor Mitinsky. By the summer of 1914, he considered this task completed and went off with his family on a well-earned vacation at Khapsalw on the Baltic. There he completed the proofreading of *Theory of Elasticity* and also continued his work on elastic stability related to ship structures. This work constitutes the forerunner of his books *Theory of Elasticity*, *Elastic Stability*, and *Plates and Shells*, published many years later in English. It was during this short vacation that World War I began, and with it the beginning of the end of the old world order.

During the early war years, Timoshenko continued and

intensified his consulting work, now directed toward aspects of the war effort—shipbuilding problems for the navy and railroad transportation—along with service to many military committees on technical matters. With the gradual disintegration of the Russian social structure, living conditions worsened. In the spring of the year of the Revolution (1917), he sent his family to the Crimea, later joining them. But even there the events of the Revolution reached them. Subsequently, he left his three children with his family in Kiev while his wife accompanied him to St. Petersburg. But she soon returned to Kiev to rejoin her family. During the Christmas holidays of 1917, he made a trip to Kiev to visit them; this turned out to be his final departure from St. Petersburg.

Kiev was held by the Communists for a short while, but in March 1918 the German army took possession. Things improved under German discipline, and Timoshenko was asked to resume his professorship at the Kiev Polytechnic Institute and to participate in the organization of the Ukrainian Academy of Sciences. Before long, German society itself began to disintegrate, and in 1919 there were rumors of the White Army advancing from the south. It arrived in Kiev at the end of August, and Timoshenko visited Rostov to negotiate further on matters of professional education with the leadership of the White Army. But it soon became apparent that this government lacked the necessary strength, and there was a great deal of mutual suspicion among Timoshenko's colleagues about the old issue of a separate Ukrainian state. During this period Timoshenko was in frequent contact with many of his former students and colleagues, all despairing about the possibility of a return to order in Russia. This led to his decision to leave Russia for good.

Through his contacts in the Ukraine he was encouraged to flee to Yugoslavia, where there seemed to be possibilities for a position. After many adventures he found himself pro-

fessor at the newly established School of Engineering in Zagreb; eventually he also succeeded in bringing his family there from Kiev. The years in Zagreb he regarded as pleasant in many ways, even though there were perpetual difficulties due to material shortages of all kinds. The stay in Zagreb from 1920 to 1922 also included visits to Western Europe and England, where he renewed his acquaintances with Love, R. V. Southwell, G. I. Taylor, and others. He also became acquainted with Piotr Kapitza during one of his trips to England. On his return to Western Europe he visited Weimar to see his friend Ehrenfest, who now held the Chair of Physics at Leyden.

Timoshenko's work in Zagreb required that he lecture in Croatian. His assistants translated his Russian lectures into Croatian, and he started the series by reading them in Croatian. In this process the Timoshenko touch was lost. In the end he decided to deliver his lectures in Russian, using as many Croatian words as possible. Eventually his students could follow him without difficulty. During this period he also found it desirable to study more English. He and his English teacher started the task of translating some of his papers into English and sending them to Professor Love, who had them published in England. Through this process the name of Timoshenko began to be known to workers in applied mechanics. To those of us who heard him lecture in English soon after his arrival in the United States, it became apparent that the Russian-Croatian combination was merely one example of his utilitarian approach to language.

His career in Zagreb came to a sudden end in 1922, when he received "a letter from America from a pupil of mine at the Petersburg Polytechnic, one Zelov,"* who was then work-

*Viktor Zelov, whose original Russian name was Tselovalnikov, subsequently became a well-known industrialist in the United States and was founder and president of the Viz Manufacturing Company in Germantown, Pennsylvania.

ing with the Vibration Specialty Company, whose president, Akimoff, was familiar with Timoshenko's work. Timoshenko was offered a position with this company and arrived in Philadelphia alone in June 1922. America depressed and frightened him. His work at the Vibration Specialty Company, although well paid, lacked focus, and his future in the new world did not appear bright. After considerable hesitation he decided to stay, however, and in the fall of 1922 he sent for his wife and youngest child—leaving the other two children in Germany. He wanted them to get a good education, and by this time he knew "that there were no good engineering schools in America."

From the vantage point in Philadelphia, Timoshenko began looking for other jobs, naturally beginning with the well-known engineering schools. He records that he received no reply from any one of these. Eventually, one of his letters reached the engineering group at the Westinghouse Electric Corporation in East Pittsburgh. He was identified by L. S. Jacobsen as the author of many interesting papers in applied mechanics, and it became this writer's pleasure to make the first contact with him. Soon after, Timoshenko received a formal offer to join the Westinghouse Research Laboratory. The details and background of this introduction of Timoshenko into American professional life will be dealt with in the following section.

By 1927 Timoshenko had become well known in the United States; in that year he joined the faculty at the University of Michigan at Ann Arbor. His position was professor of graduate mechanics, and he soon had a large following. The years of his widening influence in applied mechanics had begun. He soon had as many doctoral students as he could handle.

At Michigan, he also had his first opportunity to realize his dream of joining applied and abstract sciences. One of his

undertakings was a weekly seminar, in which he could bring together representatives from both camps. This led to a special Summer School of Applied Mechanics; distinguished teachers from universities in the United States and abroad were invited to attend, as well as representatives from industry. In this manner men such as Ludwig Prandtl, Theodore von Kármán, R. V. Southwell, G. I. Taylor, and H. M. Westergaard, among others, were brought together.

He continued his contacts with Westinghouse as a consultant, making frequent trips to East Pittsburgh during the early years. Perhaps his principal efforts related to the publishing of textbooks, the first of their kind in the United States, which were closely related to his earlier Russian books. As always, he spent his summers in Europe, visiting his favored vacation spots in Switzerland and colleagues at various universities.

In 1936 Timoshenko joined the faculty at Stanford University, where L. S. Jacobsen was then professor of mechanical engineering. In 1940 he was elected to the National Academy of Sciences. His retirement came in 1944, but he continued to live in his home in Palo Alto, lecturing at Stanford and continuing the routine of summer trips to Europe. These sunset years were placid and pleasant, but not without sorrows; his wife passed away in 1946. He was joined by his brothers and some of their families, which helped to dispel the loneliness. His traveling schedule was interrupted by World War II, and he did not really share in the scientific revival of that epoch. In 1951 the trustees of Stanford University named a new facility in his honor: The Timoshenko Laboratory for Engineering Mechanics.

In 1958 he returned to Russia for a visit and was royally received—in stark contrast to the early years in the United States when he vainly tried to get in touch with his aged father. There he visited many of the scenes of his early years.

On the whole, he felt that the Revolution had not discarded the gains in his field that he had seen during the czarist years. The immediate result of his trip was a small treatise, *Engineering Education in Russia*, published in 1959.

He then settled down to write his autobiography. It is a remarkable fact that, after nearly fifty years in the United States, he felt it necessary to write this book in Russian. It was later translated into English under the title *As I Remember* and forms a charming and unsophisticated account of a varied life.

In 1945, after the end of the war in Germany, he was driven by military personnel all over West Germany, examined what was left of the German industry and the research laboratories, and reported his findings to Washington.

During his long and productive life, Timoshenko received many honors, meticulously listed by Eugene A. Vetchorine in his foreword to *As I Remember*. He was elected a member of the Ukrainian Academy of Sciences, Kiev (1918); Russian Academy of Sciences, Leningrad-Petersburg (1928); Polish Academy of Technical Sciences, Warsaw (1935); French Academy of Sciences, Paris (1939); National Academy of Sciences, Washington, D.C. (1940); Royal Society, London (1944); and Italian Academy of Sciences, Rome (1948). Honorary doctoral degrees were conferred upon him by Lehigh University, D.Sc. (1936); University of Michigan, D.Eng. (1938); Zurich Technical Institute, D.Eng. (1947); Munich Technical Institute, D.Eng. (1949); Glasgow University, D.Laws (1951); University of Bologna, Sc.D. (1954); Zagreb Polytechnic, D.Eng. (1956); and Turin Polytechnic, Sc.D. (1960).

Beginning with the Jourowski Medal and Prize for his opus on elastic stability in 1911, he received one more award in Russia: the Salov Prize for his article on "Stresses in Rail-Type Tracks" in 1945. In the United States he received,

among others, the Worcester Reed Warner Medal from the American Society of Mechanical Engineers in 1935; the Lamme Medal from the American Society of Engineering Education in 1939; the Levy Medal from the Franklin Institute in 1944; the Cresson Medal* from the same Institute in 1958; the Grande Médaille from the Association des Ingénieurs-Docteurs in France; the coveted James Watts International Medal from the British Institution of Mechanical Engineers the same year; and the Trasenter Medal from the Association des Ingénieurs Sortis de l'Ecole de Liège in Belgium. He was the first recipient of the Timoshenko Medal, instituted in his honor by the American Society of Mechanical Engineers in 1957, and he received the James Ewing Medal from the British Institution of Civil Engineers in 1963.

## THE EARLY YEARS AT WESTINGHOUSE

With Timoshenko's arrival at Westinghouse in 1922, there was assembled in East Pittsburgh a remarkable group of young people, engaged partly to aid in the educational program of the design schools and partly to participate in research in the laboratory or to function as consultants, and sometimes as participants, in the design departments. The growing Westinghouse Club in Wilkinsburg organized evening lectures and seminars, in addition to regular daily lectures on company time. The names of the lecturers now read like a list of "Who's Who"; Timoshenko himself mentions V. Zworykin, Muromtsev, G. B. Karelitz, and J. M. Lessells; participating also were Joseph Slepian, Peters, Fortesque, and many others. Later, through Timoshenko's efforts, O. G. Tietjens and A. Nadai were added. Already enrolled in the first Mechanical Design School were V. D. Barker, H. D. Else,

*Accepted in his place by his son Gregory.

L. S. Jacobsen, B. E. James, and J. Ormondroyd; later groups included J. P. Den Hartog, R. E. Peterson, R. B. Smith, R. P. Kroon, M. D. Stone, and many others.

Timoshenko was clearly the key addition. He is sometimes thought of as the sole originator of this intellectual revival, but it is no reflection upon his contributions to observe that it had started before him and covered a range of science far beyond the narrower field of applied mechanics. To those of us who had the fortune to participate, it was our first contact with supremely good teaching and a genuine spirit of creative work in science and technology.

This writer has in his possession a small stack of notebooks, beginning with Timoshenko's "Elementary Course in Elasticity" of 1923–1924, through his "Theory of Elasticity" of 1924–1925, and continuing through a variety of other subjects until his departure from Westinghouse in 1927. But these notebooks also include lectures by Slepian ("Heaviside Operator Calculus and Plasma Physics"), Nadai ("Plasticity"), and others as well. It is clear from looking at these notes now that Timoshenko lost no time in getting back to his favorite occupation of lecturing to attentive and relatively mature students. The notes also show Timoshenko at his charming and effective best as a teacher.

The notes also indicate that after the early years, the lecture series took the form of evening courses at the Westinghouse Club, in which many of the younger people also participated. Examples from the notes are: Ormondroyd on "Graphical Integration," Den Hartog on "Bessel's Functions," Timoshenko on "Ritz' Method," Slepian on "Vector Analysis," and Soderberg on "Critical Speeds."

The intellectual atmosphere at East Pittsburgh during these years was strongly influenced by the breakthroughs in modern physics, naturally of particular interest to the physicists. Many of the international figures in science came to

lecture in Pittsburgh, which stimulated an interest in these matters, not least in the group of young engineers. There were many study groups, which, under the guidance of competent mathematicians like Slepian, were introduced to the new ideas on relativity and cosmology, quantum physics, and wave theory. It was part of Timoshenko's single-minded attention to applied mechanics, his first love, that he never played a leading role in these diversions from the main task. Similar remarks about his attitude apply to later epochs, such as when the group at South Philadelphia ran their own lecture series on classical thermodynamics, kinetic theory of gases, statistical mechanics, and other subjects. To us, his young pupils, these experiences nevertheless established directions of interest that we have followed through the rest of our lives.

The notes also hint at a spirit of revival, which one encounters on only a few precious occasions during one's life. Many such periods have come and gone since, but to us, young men of the early twenties, those years in dreary and sooty East Pittsburgh on Turtle Creek have a sheen of their own.

## CONCLUSION

On his arrival at East Pittsburgh in 1923, Timoshenko thus entered an intellectual environment that seems to have been made expressly for him and to which he made great contributions. He was in his forties, had a striking appearance, wore a beard, and, to those of us still in our twenties who came under his influence, he was a wise old man with a keen sense of humor. His own recollections of the Hiking Club quite accurately portray the influence he had upon us. It is significant that his first effort in the research laboratory was devoted to the establishment of a Mechanics Section—a literal extension of his earlier observations and experiences in

Russia and Europe. He gradually became the apostle of applied mechanics; with G. M. Eaton and John Lessells he was one of the enthusiastic founders of the Applied Mechanics Division of the American Society of Mechanical Engineers, perhaps one of the most significant contributions to come from that Society.

Only gradually did we come to appreciate the turmoil and anxiety that had been his lot during the preceding years. Under the charming exterior there was a deep-seated disappointment in American culture, which to Timoshenko and his wife seemed crude and uncouth in comparison with their experiences in the Ukrainian countryside and in the cultural circles of Europe. He was still smarting under the effects of the cataclysm of his homeland, which prevented him from reunion with his aged father. Out of these experiences grew a strange love-hate relationship in his feelings toward America, which never left him and sometimes stood in the way of full utilization of his talents. In reading *As I Remember,* one is astonished at the absence of a single word in grateful recognition of his debt to America, which had awarded him such a rare opportunity.*

Americans were accustomed to immigrants who developed an uncritical admiration for their new homeland, often accompanied by bitter hostility toward their place of birth. But to many of us, who also were immigrants with strong cultural roots in the homeland, Timoshenko's attitude was at least understandable. Through the years of turmoil—the late twenties, the depression, and the years just prior to World War II—this attitude of Timoshenko's did not appear to soften. These feelings culminated during his trip to Russia in 1958, when he became, so to speak, reunited with his homeland. But it was largely a reunion with the homeland of his

* Also noted in the review of *As I Remember* by J. P. Den Hartog, *Science,* 160(1968).

dreams and with the successors to the old institutions. It is significant, as observed earlier, that his accounts of his life following this trip were written in Russian—this from the author of dozens of successful textbooks in English. It is also worth observing that circumstances prevented him from fully sharing in the wave of scientific revival that was part of the World War II scene. The experience of the first epoch of American superiority in scientific and technological developments was somehow denied him.

But whatever there was of bitterness was encased within his innermost being. The principal recollection on the part of those of us who were privileged to know him during those first years on the American scene is that of a man of great wisdom and a keen sense of humor, enhanced by his special version of the English language. This was usually devoid of articles and retained the syntax of Russian, mixed with that of other languages. When confronted with examples of American colloquialisms, his favorite expression was a quizzical "What means this?" Some of us who had the opportunity to accompany him to international conferences—the Congress of Applied Mechanics in Zürich in 1926 is an example—also were privileged to sense the enormous range of his acquaintances in the scientific world, acquired during his years of travel. The initial impression was of a remarkable linguistic versatility on his part, but this impression was tempered when it was discovered that he spoke only one language, modified in the international circles with French or German phrases, depending on the makeup of his audience. His Russian was flawless but always retained the strong Ukrainian accent.

While Timoshenko was well known in professional circles all over the world, the number of people admitted to his innermost sphere of affection was not large. His former students had a special position; so did a small group of his

early acquaintances in the United States. One has the impression, however, that real intimacy was reserved for his own family* and his Russian-speaking friends. Among those who might be mentioned are G. B. Karelitz, who passed away in 1940, and Vladimir Zworykin. Professor Leonid M. Tichvinsky, in a personal communication, observed that "Timoshenko was the last person who knew my parents; he was my best man when I married my first wife, coming from Ann Arbor to Pittsburgh for this occasion in 1935." In a later communication Professor Tichvinsky observed that Timoshenko, while leading a comfortable life in the United States, did not accumulate any substantial wealth. He left a modest legacy to be divided among his children. The royalties from all his books were assigned to Stanford University.

In the perspective of more than a half century, Timoshenko's great influence upon applied science and technology in America resulted less from his original, creative discoveries than from his ideals of engineering education, his superb skill as a teacher, and his highly developed pragmatic skill in using fragments of exact solutions for a variety of approximate solutions to difficult problems in applied mechanics. Examples of this are his skillful use of the solutions for beams on elastic foundations to problems such as railroad rails and to details of machinery such as highly stressed dovetail joints. Another example is his frequent use of the Boussinesq solutions to a variety of intractable problems in machine structures. He also clarified the premises of the Rayleigh-Ritz iteration method, extending it to a variety of problems in elasticity and dynamics. Throughout all his

* He was a member of a remarkable family, which contributed much to his worldwide views and connections. Of his two younger brothers, Serhij (an architect) was Secretary of Transportation in the Ukrainian government in the early 1920's, while Vladimir (an economist) was Secretary of Commerce of the Ukraine and later Chief of Statistics of the AAA under President Franklin D. Roosevelt in Washington and at Stanford University.

work there is a pragmatic attitude toward mathematics, and even to theoretical mechanics, which was regarded as one of his great sources of strength.

This charming pragmatism was new to most of us and seemed of immense value to the practicing engineers. It is well to remember that even elementary computer aids, which we now take for granted, were then many years distant in the future. Iteration procedures had to be worked out with brute strength and untold man-hours. With the development of modern computers and new methods such as the finite-element method, many problems once beyond our reach have now become routine. The pragmatic approach may now seem less essential, but I believe this is only a temporary phase. In any case, the effectiveness and charm of Timoshenko's teaching will always be a treasured memory to his students.

A FACTUAL ACCOUNT of the career of Stephen P. Timoshenko has been condensed from his book *As I Remember,* aided by tributes and memoirs by former students and associates, particularly those of Professor D. H. Young of Stanford University (Donovan H. Young, "Stephen P. Timoshenko 1878–1972," *Applied Mechanics Review*, July 1972. 5 pp.) and Professor Chia-Shun Yih of the University of Michigan (Chia-Shun Yih, "Stephen P. Timoshenko: A Portrait in Miniature." A note to the faculty of the College of Engineering, October 30, 1972.). These tributes emphasize his years in American universities.

Since this writer and a few remaining colleagues were part of the group that first became associated with Timoshenko on his arrival, in 1923, at the Westinghouse Electric Corporation in East Pittsburgh, Pennsylvania, we wished to record some of the background and impressions from his early years there. In the preparation of this memoir I have been greatly assisted by the members of the "International Hiking Club" in Wilkinsburg—Professors J. P. Den Hartog, J. Ormondroyd, and L. S. Jacobsen—as well as by other members of the group, specifically R. E. Peterson, M. Stone, and Leonid M. Tichvinsky, whose contributions and criticisms I gratefully acknowledge.

## BIBLIOGRAPHY

1905

Torsional vibrations of shafts. Proc. St. Petersburg Polytech. Inst., 3:55–106.

Krylov's method for integration of ordinary differential equations. Proc. St. Petersburg Polytech. Inst., 3:397–406.

Formulas for combined stresses from various strength theories. Proc. St. Petersburg Polytech. Inst., 3:415–55.

1906

Lateral buckling of I-beams under the influence of forces acting in the plane of largest rigidity. Proc. St. Petersburg Polytech. Inst., 4:151–219; 5(1–2):3–34, 262–92.

1907

Stresses in a plate with a circular hole. Proc. Kiev Polytech. Inst., 9:95–113.

Secondary stresses caused by rigidity of joints. Proc. St. Petersburg Polytech. Inst., 7:135–44.

Buckling of a bar on an elastic foundation. Proc. St. Petersburg Polytech. Inst., 7:145–57.

Forced vibration of prismatic bars. Proc. Kiev Polytech. Inst. 9: 201–52.

*Stability of Plates under Compression.* Kiev: Kulzhenko Typography. 60 pp.

1908

On the subject of buckling. Proc. Kiev Polytech. Inst., 8:181–212.

*Strength of Materials.* Part 1. Kiev: Kiev Polytechnic Institute. 373 pp.

*Collection of Problems in Strength of Materials.* Kiev: Kiev Polytechnic Institute.

1909

*A Course in Elasticity Theory.* Part 1. Kiev: Kiev Polytechnic Institute.

Stresses in a circular ring compressed by two opposing forces. Proc. Kiev Polytech. Inst., 9:21–37.

1910

Application of normal coordinates in analyzing the bending of bars and plates. Proc. Kiev Polytech. Inst., 10:1–19.

Stability of elastic systems. Proc. Kiev Polytech. Inst., 10:147–67.
Stability of elastic systems. Proc. Kiev Polytech. Inst., 10:375–560.
Einige Stabilitätsprobleme der Elastizitätstheorie. Z. Math. Phys., 58:337–85.

1911

*An Approximate Method for Investigating the Stability of Elastic Systems.* Kiev: St. Vladimir University. 25 pp.
*A Course in Strength of Materials.* Kiev: Kiev Polytechnic Institute. 517 pp.
Erzwungene Schwingungen prismatischer Stäbe. Z. Math. Phys. 59:163–203.

1912

Problems of strength of steam turbines. J. Soc. Technol. St. Petersburg, 7:266–79.
Effect of impact on a beam. Proc. St. Petersburg Polytech. Inst., 17:407–25.

1913

Bending of bars having a slight curvature. J. Soc. Technol. St. Petersburg, 13:411–14.
Bending of spherical shells. J. Soc. Technol. St. Petersburg, 17: 549–57.
Plotting the deflection curve. J. Soc. Technol. St. Petersburg, 21: 241–42.
Use of stress functions to study flexure and torsion of prismatic bars. St. Petersburg. 21 pp. (Reprinted in: Mem. Inst. Ways Commun., 82:1–21.)
Sur la stabilité des systèmes élastiques. Ann. Ponts Chaussées, 1st part, Mémoires et Documents, 9th Ser., 13:496–566; 16:72–132, 373–412.
Zur Frage nach der Wirkung eines Stosses auf einen Balken. Z. Math. Phys., 62:198–209.

1914

Stability of a cylindrical shell. J. Soc. Technol. St. Petersburg, 21:785–92.
Effect of initial curvature on the bending of a rectangular plate. Petrograd. 4 pp. (Reprinted in: Mem. Inst. Ways Commun., 89.)

Etude de la flexion des barres au moyen d'une méthode approximative. Ann. Trav. Publics. Belg., 71 Ser., 219:263–96.

1915

Strength of rails. Proc. Inst. Ways Commun. 42 pp.
Large deflections of circular plates. Petrograd. 10 pp. (Reprinted in: Mem. Inst. Ways Commun., 89.)
Stability of plates with stiffening ribs. Petrograd. (Reprinted in: Mem. Inst. Ways Commun., 89.)
Vibration of rails. Proc. Inst. Electr. Eng., Petrograd, 13.

1916

The effect of clearances between the rail and the tie on bending of rails. Mem. Inst. Ways Commun. 14 pp.
*A Course in Elasticity Theory.* Part 2. St. Petersburg.

1917

Allowable stresses in railway bridges. Proc. Inst. Ways Commun., 7.

1919

Use of trigonometric series for calculation of suspension bridges. Eng. J., 8:239–43.

1921

Über die Stabilität versteifter Platten. Eisenbau, 12:147–63.
Etude de l'action des charges roulantes sur les rails. Génie Civ., 79:555–56.
On the correction for shear of the differential equation for transverse vibrations of prismatic bars. Philos. Mag., 41:744–46.

1922

*A Course of Statics of Structures.* Parts 1 and 2. Petrograd. 344 pp.
Über dies Biegung der allseitig unterstützten rechteckigen Platte unter Wirkung einer Einzellast. Bauingenieur, 3:51–54.
Beams with loads irregularly distributed. Engineering, 113:196–97.
*Calcul des Arcs Elastiques*, ed. Ch. Béranger. Paris: Librairie Polytechnique. 77 pp.
On the transverse vibrations of bars of uniform cross-sections. Philos. Mag., 43:125–31.

On the forced vibration of bridges. Philos. Mag., 43:1018–19.
On the distribution of stresses in a circular ring compressed by two forces acting along a diameter. Philos. Mag., 44:1014–19.
On the torsion of a prism, one of the cross-sections of which remains plane. Proc. Lond. Math. Soc., Ser. 2, 20:389–97.
A membrane analogy to flexure. Proc. Lond. Math. Soc., Ser. 2, 20:398–407.
Elasticity of pipe bends. Trans. Am. Soc. Mech. Eng., 44:585–93.
Torsion of crankshafts. Trans. Am. Soc. Mech. Eng., 44:653–67.
Berechnung der Schubspannungen im gebogenen Balken. Z. Angew. Math. Mech. 2:160–61.

1923

Determination of the modulus of elasticity. Mech. Eng., 45:259–60.
The pendulum hardness tester. Engineer, 136:21.
Bending stresses in curved tubes of rectangular cross-section. Trans. Am. Soc. Mech. Eng., 45:135–40.
The bending and torsion of multi-throw crankshafts on many supports. Trans. Am. Soc. Mech. Eng., 45:449–70.
Kippsicherheit des gekrümmten Stabes mit kreisförmiger Mittellinie. Z. Angew. Math. Mech., 3:358–62.

1924

Über die Biegung von Stäben, die eine kleine anfängliche Krümmung haben. In: *Festschrift zum siebzigsten Geburtstage August Föppls*, pp. 74–81. Berlin: Springer-Verlag.
On stresses in a plate with a circular hole. J. Franklin Inst., 197: 505–16.
An approximate method of solution of two dimensional problems in elasticity. Philos. Mag., 47:1095–104.
Beams without lateral support. Trans. Am. Soc. Civ. Eng., 87: 1247–62.
Deflections of a uniformly loaded circular plate with clamped edges. Sci. Pap. No. 162, Westinghouse Electric and Manufacturing Co.

1925

Analysis of bi-metal thermostats. J. Opt. Soc. Am., 11:233–55.
Properties of matter under high pressure. Mech. Eng., 47:513–15.
With W. Dietz. Stress concentration produced by holes and fillets.

Trans. Am. Soc. Mech. Eng., 47:199–220.

With J. M. Lessells. *Applied Elasticity.* New York: D. Van Nostrand Co.

1926

With R. V. Baud. The strength of gear teeth. Mech. Eng., 48: 1105–9.

Method of analysis of statical and dynamical stresses in rail. In: *Proceedings of the Second International Congress for Applied Mechanics,* pp. 407–18. Zurich and Leipzig: Orell Füssli Verlag.

Stress concentration produced by fillets and holes. In: *Proceedings of the Second Congress for Applied Mechanics,* pp. 419–26. Zurich and Leipzig: Orell Füssli Verlag.

1927

Vibration of bridges. Trans. Am. Soc. Mech. Eng., 49–50(part 2): 53–61.

1928

Vibration problems in engineering. N.Y.: D. Van Nostrand Co.

The stiffness of suspension bridges. Atti Congr. Int. Mat. (Proc. Int. Congr. Math.), Bologna, 6:305–6.

Steifigkeit von Hängebrücken. Z. Angew. Math. Mech., 8:1–10.

1929

Teaching of advanced mechanics in engineering schools. Mech. Eng., 51:609–10.

1930

Vibration problems. In: *Marks' Mechanical Engineering Handbook,* pp. 489–502. New York: McGraw-Hill.

The theory of elasticity. Mech. Eng., 52:494–96.

Recent developments in the application of mechanics to machine design. Mech. Eng., 52:607–10.

*Strength of Materials.* 2 vols. Princeton, N.J.: D. Van Nostrand Co.

Problems concerning elastic stability in structures. Trans. Am. Soc. Civ. Eng., 94:1000–1020.

1931

Stability and strength of thin-walled constructions. In: *Proceedings of the Third International Congress for Applied Mechanics,* vol. 3, pp.

3–15. Stockholm: Kungl. Boktryckeriet, P. A. Norstedt and Söner.

Stabilitätsprobleme der Elastizität. In: *Handbuch der physikalischen und technischen Mechanik,* ed. F. Auerbach and W. Hort, vol. 4, part 1, pp. 81–145. Leipzig: J. A. Barth.

Festigkeitsprobleme im Maschinenbau. In: *Handbuch der physikalischen und technischen Mechanik,* ed. F. Auerbach and W. Hort, vol. 4, part 1, pp. 146–98. Leipzig: J. A. Barth.

Theory of elasticity. Mech. Eng., 53:889–90.

1932

Stability of plate girders subjected to bending. Congr. Int. Assoc. Bridge Struct. Eng., Zurich, pp. 129–47.

With B. F. Langer. Stresses in railroad track. Trans. Am. Soc. Mech. Eng., 54:277–302.

1933

Working stresses for columns and thin-walled structures. Trans. Am. Soc. Mech. Eng., 55:APM 173–83.

Über die Biegung von Trägerrosten. Z. Angew. Math. Mech., 13: 153–59.

With S. Way. Suspension bridges with a continuous stiffening truss. Publ. Int. Assoc. Bridge Struct. Eng., Zurich, 2:452–66.

1934

The stability of the webs of plate girders. Engineering, 138:207–9.

*Theory of Elasticity.* New York: McGraw-Hill.

1935

*Elements of Strength of Materials.* Princeton, N.J.: D. Van Nostrand Co.

Buckling of flat curved bars and slightly curved plates. J. Appl. Mech., 2:A17–A20.

1936

*Theory of Elastic Stability.* N.Y.: McGraw-Hill.

1937

With D. H. Young. *Engineering Mechanics.* New York: McGraw-Hill.

1938

Bending of rectangular plates with clamped edges. In: *Proceedings of the Fifth International Congress of Applied Mechanics,* pp. 40–43. New York: John Wiley & Sons.

1940

*Theory of Plates and Shells.* New York: McGraw-Hill.

1941

The forced vibrations of tie-rods. In: *Theodore von Kármán Anniversary Volume, Contributions in Applied Mechanics,* pp. 226–30. Friends of Theodore von Kármán.

1942

Teaching dynamics. J. Eng. Educ., 32:463–66.

1943

Theory of suspension bridges. J. Franklin Inst., 235:213–38, 327–49.

1945

Theory of bending torsion and buckling of thin-walled members of open cross-section. J. Franklin Inst., 239:201–19, 249–68, 343–61.

With D. H. Young. *Theory of Structures.* New York: McGraw-Hill.

1947

Stress concentration and fatigue failures. Proc. Inst. Mech. Eng., London, 157:163–69.

1948

With D. H. Young. *Advanced Dynamics.* New York: McGraw-Hill.

1950

D. J. Jourawski and his contribution to theory of structures. In: *Federhofer-Girkmann-Festschrift, Beiträge zur angewandten Mechanik,* pp. 115–23. Vienna: Franz Deutickle Verlag.

1953

History of the development of strength of materials in Russia. Academia Nazionale dei Lincei, Rome, no. 29. 8 pp.

*History of Strength of Materials.* New York: McGraw-Hill.

1954

Stress concentration in the history of strength of materials. Proc. Soc. Exp. Stress Anal., 12:1–12.

1956

The development of engineering education in Russia. Russian Rev., 15:173–85.

1958

The background of engineering education in Russia. J. Eng. Educ., 49:122–25.

1959

*Engineering Education in Russia.* New York: McGraw-Hill.

1968

*As I Remember* (Autobiography). New York: D. Van Nostrand Co.

## RELATED BOOKS

*Stephen Timoshenko 60th Anniversary Volume,* Contributions to the Mechanics of Solids Dedicated to Stephen Timoshenko by His Friends. New York: The Macmillan Co., 1938.

*The Collected Papers of Stephen P. Timoshenko.* New York: McGraw-Hill, 1953.