

Foreword

Special Issue: The Contributions of Jorgen W. Lund to Rotor Dynamics



Jorgen W. Lund

August 7, 1930–November 16, 2000

This special issue is dedicated to the life and work of Jorgen W. Lund. The majority of the papers in this issue were presented in a special session in honor of Jorgen Lund, at the 2001 ASME Vibrations Conference, Pittsburgh, PA, September 10, 2001. It was a truly high honor for me to have organized the sessions in 2001 and I am equally happy that ASME has agreed to publish this tribute to the work of Lund in this special issue. The suggestion for this special issue was made by the editor, Lawrence A. Bergman.

R. Gordon Kirk

May 15, 2003

This issue of the Journal of Vibration and Acoustics is devoted to the late Jorgen Lund and his many contributions to the field of rotor dynamics. I am indebted to Professor R. Gordon Kirk for suggesting this special tribute to Dr. Lund, and for assuming editorial responsibility for this issue of the journal

Lawrence A. Bergman

Urbana, Illinois

June 25, 2003

Jørgen W. Lund

Jørgen Lund was a modest, gentle and kind friend of many professional engineers worldwide. In addition, he was an innovative engineer and easily developed original new ground-breaking concepts as a world class researcher. His work experience included both industry and academia. He first worked for Kockums Mechanical Works in Sweden in 1955. In 1956 he came to the United States where he worked in research for General Electric, Lynn, from 1956 to 1959, Boeing from 1959 to 1960, General Electric, Schenectady, from 1960 to 1961 and then Mechanical Technology, Inc as manager, vibrations. In 1967 he returned to his homeland, Denmark, where he was associate professor of engineering at The Technical University of Denmark. He was promoted to the rank of full professor in 1990. Jørgen Lund retired from The Technical University of Denmark in the spring of 1995, after a long and notable career. He continued to do consulting and was working on special assignments for Ødegaard & Danneskiold-Samsøe A/S (ØDS), in Copenhagen since his retirement from The Technical University.

Lund developed numerous original bearing analysis design programs including the analysis of tilting pad bearings by a pad assembly procedure. These bearings and his analysis remains the basic analytic method for the industry standard tilting pad fluid film bearing in most all critical path, land based rotating machinery. He was the first person to develop and understand the importance of the whirl frequency ratio for fluid film bearings and to begin evaluating

the stability performance of fixed geometry bearings using these parameters. He received his Ph.D. in mechanics from Rensselaer Polytechnic Institute in 1966. His dissertation was the first serious attempt to examine the nonlinear phenomena of a rotor supported in plain fluid film journal bearings. He and his associates at MTI were the first to develop bearing design guides and design charts for both liquid and gas, hydrodynamic and hydrostatic bearing designs. Lund's methods are still used to evaluate bearing performance. Jørgen Lund also developed what has now become the industry standard for calculation of damped critical speeds of flexible rotor bearing systems. This added to his original elliptical orbit synchronous forced response analysis of flexible rotor bearing systems including massive flexible bearing pedestal effects. These programs are still being applied today in rotating machinery industries worldwide.

Jørgen Lund received the Danish ESSO Award in 1967, the Achievement Award at the International Symposium in Rotating Machinery, 1988, and was nominated for the 2001 ASME den Hartog Award in Vibrations Engineering. In 1987 Lund was invited to repeat one of the previous papers that he had presented at the ASME Design Division Vibrations Conference. He elected to give the outstanding paper from the 1973 conference, "Stability and Damped Critical Speeds of a Flexible Rotor in Fluid-Film Bearings." He was the author of a text on rotor dynamics published in 1979 and he published over 50 technical papers of the very highest quality plus numerous design and research contract reports. He was a member of the Honorary Scientific Research Society, Sigma Xi. While at the Technical University of Denmark, Jørgen Lund taught courses in lubrication theory and machinery dynamics. On the average, 10 students took these courses. In addition he had one or two students for their master theses each year. He has supervised 6 Ph.D. students. He was an external examiner to Ph.D. theses for several European technical universities. Any person that works in the field of rotating machinery has had their life impacted by Lund's work. The authors with papers in this special publication have been especially fortunate to have known Jørgen Lund, maybe better than most. Their papers and words will speak for each of these authors. In addition, examples of comments from a few engineers that have also known Lund and the worth of his works are given here.

"I can only express my condolences from my heart. I remember his great contributions to our field of science and his warm personality. I have many fond memories of him. Sincerely, a friend of Jorgen Lund." **Prof. Yukio Hori**

"In my opinion, Dr. Jorgen W. Lund is the most recognized technologist of rotating machinery vibration in the second half of the 20th century. His high degree of recognition is an accurate measure of his considerable technical contributions to rotor dynamics technology In addition to being the top person in his professional field, Jorgen Lund was quite a fine human being. As great a loss as his passing is to us in the field of rotor dynamics, the loss to his wife and family is by comparison immeasurable. I hope that their knowledge of the high professional and personal esteem in which he is held by all of us in his field provides some measure of comfort to them in their grief." **Prof. Maurice L. Adams, Jr.**

"I'm very pleased that you've undertaken to organize this very fitting tribute to Jorgen. I suggest you consult the nomination document (for the den Hartog Award nomination) which Tony Smalley assembled to identify the letters of tribute in which I and many, many others documented our recollections of Jorgen's contributions." **Fred Ehrich**

"He was a friend of mine and an outstanding contributor to the field of rotor dynamics." **Ronald L. Eshleman**

"A major loss to our community. He will be greatly missed." **Dr. John Kocur**

"For well over thirty years the rotating equipment industry has used the rotor dynamic programs that Lund developed for the analysis of the lateral vibration characteristics of rotating machinery. The "Lund" analysis has become a standard step in the design of rotating equipment, in the issuance of API acceptance reports, and the investigation of test and field problems. I am sure that every day of the year somebody somewhere in the world is running his rotor dynamic computer codes. His rotor response program is the standard of the rotating equipment industry. His tilt pad bearing program, or some version that was inspired by this program, is used throughout the rotating equipment industry. His lateral stability program is the most important contribution to rotor dynamics, specifically in the analysis of instability problems at the first natural frequency and in the design of centrifugal compressors to resist sub-synchronous vibration. The literature is filled with references to the use of the Lund stability program. . . ." **Dr. Edmund A. Memmott**

"The news of Jorgen's passing away was devastating to me personally. He was a close friend, a valued colleague and a technology pioneer. He was what I would term an unassuming, versatile genius. The field of dynamics of rotors in general was where major contributions were made. These contributions included critical speed determination, rotor response to unbalance, spring and damping characteristics of bearings, fluid film bearing pad analysis, rotor stability analysis, design of dampers and damping systems and the design analysis of hydrostatic and tilting pad gas bearings Jorgen was on the "front lines" since it was to him that we turned to explain what we needed to be able to do and to ask that he develop the necessary computer tools. Speaking for myself, I never brought Jorgen a problem that he couldn't solve. Nor, did he ever provide me with a solution that I couldn't use It has been a joy and a privilege to know and work closely with Jorgen Lund." **Paul Lewis**

Jørgen Lund is survived by his wife Gudrun Lund, a daughter, two sons and five grandchildren.

Major Publications by Jorgen W. Lund

J. W. Lund and B. Sternlicht, "Rotor-Bearing Dynamics with Emphasis on Attenuation," *Journal of Basic Engineering, Trans. ASME*, Vol. 84, Series D, 1962, pp. 491–502.

J. W. Lund, "Spring and Damping Coefficients for the Tilting Pad Journal Bearing," *Trans. ASLE*, Vol. 7, 1964, pp. 342–352.

J. W. Lund, "The Stability of an Elastic Rotor in Journal Bearings with Flexible, Damped Supports," *Journal of Applied Mechanics, Trans. ASME*, Vol. 87, Series E, 1965, pp. 911–920.

J. W. Lund, "The Hydrostatic Gas Journal Bearing with Journal Rotation and Vibration," *Journal of Basic Engineering, Trans. ASME*, Vol. 86, Series D, 1964, pp. 328–326.

J. W. Lund, "A Theoretical Analysis of Whirl Instability and Pneumatic Hammer for a Rigid Rotor in Pressurized Gas Journal Bearings," *Journal of Lubrication Technology, Trans. ASME*, Series F, Vol. 89, 1967, pp. 154166.

- J. W. Lund and F. K. Orcutt, "Calculations and Experiments on the Unbalance Response of a Flexible Rotor," *Journal of Engineering for Industry, Trans. ASME*, Vol. 89, Series B, No. 4, Nov. 1967, pp. 785–796.
- J. W. Lund and E. Saibel, "Oil Whip Whirl Orbits of a Rotor in Sleeve Bearings," *Journal of Engineering for Industry, Trans. ASME*, Vol. 89, Series B, No. 4, Nov. 1967, pp. 813–823.
- J. W. Lund, "Calculation of Stiffness and Damping Properties of Gas Bearings," *Journal of Lubrication Technology, Trans. ASME*, Vol. 90, Series F, 1968, pp. 793–803.
- J. W. Lund, "Self-Excited, Stationary Whirl Orbits of a Journal in a Sleeve Bearing," Ph.D. Thesis, Rensselaer Polytechnic Institute, Troy, N.Y., 1966.
- J. W. Lund and J. H. Vohr, "A Note on Design Data for Hydrostatic Gas Bearings," Gas Bearing Symposium on Design Methods and Applications, University of Southampton, 1967, pp. A29–A38.
- J. W. Lund and J. Tonnesen, "Analysis and Experiments on Multi-Plane Balancing of a Flexible Rotor," *Journal of Engineering for Industry, Trans. ASME*, Vol. 94, Series B, No. 1, Feb. 1972, pp. 233–242.
- J. W. Lund, "Stability and Damped Critical Speeds of a Flexible Rotor in Fluid-Film Bearings," *Journal of Engineering for Industry, Trans. ASME*, Vol. 96, Series B, No. 2, May 1974, pp. 509517.
- J. W. Lund, "Modal Response of a Flexible Rotor in Fluid-Film Bearings," *Journal of Engineering for Industry, Trans. ASME*, Vol. 96, Series B, No. 2, May 1974, pp. 525–533.
- J. W. Lund, "Some Unstable Whirl Phenomena in Rotating Machinery," *The Shock and Vibration Digest*, Vol. 7, No. 6, June 1975, pp. 5–12. (The Shock and Vibration Center, Naval Research Laboratory, Washington, DC 20375).
- E. Reinhardt and J. W. Lund, "The Influence of Fluid Inertia on the Dynamic Properties of Journal Bearings," *Journal of Lubrication Technology, Trans. ASME*, Vol. 97, Series F, No. 2, April 1975, pp. 159–167.
- J. W. Lund, "Response Characteristics of a Rotor with Flexible, Damped Supports," *Dynamics of Rotors*, F. I. Niordson, ed., Springer Verlag, 1975, pp. 319–349.
- K. K. Thomsen and J. W. Lund, "Consideration of Film Rupture in the Inlet Zone of a Journal Bearing," Proc. 1st Leeds-Lyon Symposium on Tribology: Cavitation and Related Phenomena in Lubrication, D. Dowson and C. M. Taylor, eds. The Institute of Mechanical Engineers, London, 1975, pp. 163–167.
- E. Christensen, J. Tonnesen and J. W. Lund, "Dynamic Film Pressure Measurements in Journal Bearings for Use in Rotor Balancing," *Journal of Engineering for Industry, Trans. ASME*, Vol. 98, Series B., No. 1, Feb. 1976, pp. 92–100.
- J. W. Lund, "Linear Transient Response of a Flexible Rotor Supported in Gas-Lubricated Bearings," *Journal of Lubrication Technology, Trans. ASME*, Vol. 98, Series F, No. 1, January 1976, pp. 57–65.
- J. W. Lund, "A Method for Using the Free Shaft Modes in Rotor Balancing," Proceedings of Conference on Vibrations in Rotating Machinery, The Institution of Mechanical Engineers, London 1976, pp. 65–71.
- J. Tonnesen and J. W. Lund, "Some Experiments on Instability of Rotors Supported in Fluid Film Bearings," *Journal of Mechanical Design, Trans. ASME*, Vol. 100, No. 1, January 1978, pp. 147–155.
- J. W. Lund, "Critical Speeds, Stability and Response of a Geared Train of Rotors," *Journal of Mechanical Design, Trans. ASME*, Vol. 100, No. 3, July 1978, pp. 535–539.
- J. W. Lund and K. K. Thomsen, "A Calculation Method and Data for the Dynamic Coefficients of Oil-Lubricated Journal Bearings," *ASME Publication: Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization*, 1978, pp. 1–28.
- J. W. Lund, "Response by Normal Coordinates of a Structure Interacting with a Fluid," *Dynamics of Multibody Systems*, K. Magnus, ed., IUTAM Symposium 1977, Springer Verlag, 1978, pp. 196–207.
- J. W. Lund, "Evaluation of Stiffness and Damping Coefficients for Fluid Bearings," *The Shock and Vibration Digest*, Vol. 11, No. 1, January 1979, pp. 5–10.
- J. W. Lund, "Sensitivity of the Critical Speeds of a Rotor to Changes in the Design," *Journal of Mechanical Design, Trans. ASME*, Vol. 102, No. 1, January 1980, pp. 111–121.
- J. W. Lund, "Review of Analytical Methods in Rotor-Bearing Dynamics," *Tribology International*, Vol. 13, No. 5, October 1980, pp. 233–236.
- J. W. Lund and H. B. Nielsen, "Instability Threshold of an Unbalanced Rigid Rotor in Short Journal Bearings," Proceedings of Second International Conference on Vibrations in Rotating Machinery, Cambridge, Sept. 2–4, 1980. The Institution of Mechanical Engineers, London, 1980, pp. 91–95.
- O. Pinkus and J. W. Lund, "Centrifugal Effects in Thrust Bearings and Seals under Laminar Conditions," *Journal of Lubrication Technology, Trans. ASME*, Vol. 103, No. 1, January, 1981, pp. 126–136.
- J. W. Lund, "The Pivoted, Spherical Cap Slider Bearing," *Journal of Lubrication Technology, Trans. ASME*, Vol. 104, No. 2, April 1982, pp. 216–219.
- J. W. Lund, "Current Topics in Rotordynamics Research," *The Shock and Vibration Digest*, Vol. 14, No. 6, June 1982, pp. 3–7.
- P. K. Hansen and J. W. Lund, "An Analytical Study of the Heat Balance for a Journal Bearing," NATO Conference "Problems in Bearings and Lubrication," AGARD Conference Proceedings AGARD-CP-323, June 1982, pp. 25–1 to 25–9.
- J. W. Lund, A. J. Smalley, J. A. Tecza and J. F. Walton, "Squeeze Film Damper Technology. Part 1: Prediction of Finite Length Damper Performance," Paper No. 83-GT-247. ASME.
- J. W. Lund and P. K. Hansen, "An Approximate Analysis of the Temperature Conditions in a Journal Bearing. Part I: Theory," *Journal of Tribology, Trans. ASME*, Vol. 106, No. 2, April 1984, pp. 228–236.
- J. W. Lund and J. Tonnesen, "An Approximate Analysis of the Temperature Conditions in a Journal Bearing. Part 11: Application," *Journal of Tribology, Trans. ASME*, Vol. 106, No. 2, April 1984, pp. 237–245.
- Z. Wang and J. W. Lund, "Calculations of Long Rotors with Many Bearings on a Flexible Foundation," Third International Conference on Vibration in Rotating Machinery, York, September 11–13, 1984, The Institution of Mechanical Engineers Conference Publication 1984-10, London, pp. 13–15.

J. W. Lund and Z. Wang, "Application of the Riccati Method to Rotor Dynamic Analysis of Long Shafts on a Flexible Foundation," *Journal of Vibrations, Acoustics, Stress and Reliability in Design, Trans. ASME*, Vol. 108, No. 2, April 1986, pp. 177–181.

P. Klit and J. W. Lund, "Calculation of the Dynamic Coefficients of a Journal Bearing, Using a Variational Approach," *Journal of Tribology*, Vol. 108, No. 3, July 1986, pp. 421–425.

J. W. Lund, "Destabilization of Rotors from Friction in Internal Joints with Micro-Slip," International Conference on Rotordynamics, Sept. 14–17, 1986, Tokyo, pp. 487–491.

J. W. Lund, "Review of the Concept of Dynamic Coefficients for Fluid Film Journal Bearings," *Journal of Tribology, Trans. ASME*, Vol. 109, No. 1, January 1987, pp. 37–41.

J. W. Lund and L. B. Pedersen, "The Influence of Pad Flexibility on the Dynamic Coefficients of a Tilting Pad Journal Bearing," *Journal of Tribology, Trans. ASME*, Vol. 109, No. 1, January 1987, pp. 65–70.

J. W. Lund, "Rotor-Bearing Foundation Systems," Seventh IFToMM Congress, Theory of Machines and Mechanisms, Sevilla, Spain, 1987, 5 pages.

J. W. Lund, "Keynote Paper: Topics in Rotor Dynamics," *The Second International Symposium on Transport Phenomena, Dynamics and Design of Rotating Machinery*, Honolulu, Hawaii, April 3–6, 1988, pp. 205–211.

J. Tonnesen and J. W. Lund, "Impact Excitation Tests to Determine the Influence Coefficients for Balancing Lightly Damped Rotors," *Journal of Engineering for Power, Trans. ASME*, Vol. 110, No. 4, October 1988, pp. 600–604.

J. Tonnesen and J. W. Lund, "Impact Excitation Tests on a Rotor Supported in Ball Bearings," Proceedings of the Institution of Mechanical Engineers, *Vibrations in Rotating Machinery*, IMechE 1988-7, pp. 223–228.

J. W. Lund, "A Method for Dynamics Calculations of Rotor Bearing Foundation Systems," Proceedings of NATO/ADVANCED STUDY INSTITUTE: Vibration and Wear Damage in Rotating Machinery, Troia Beach, Portugal, April 10–22, 1989. NATO-ASI-Series, Series E, Vol. 174, 1990, pp. 593–603.

J. W. Lund, "Dynamic Coefficients for Fluid Film Journal Bearings," *ibid.* pp. 605–616.

J. W. Lund, "Destabilization of Rotors from Friction in Internal Joints," *ibid.* pp. 617–629.

J. Tonnesen and J. W. Lund, "Modal Parameter Identification by Impact Excitation Tests of a Rotor Supported in Oil-Film Bearings," Proceedings of IFToMM, 3rd. Int. Conference on Rotordynamics, Lyon, France, Sept. 10–12, 1990, pp. 437–443.

J. W. Lund, "Comments on Modal Analysis of Rotors," Proceedings of 11th NRCC Machinery Dynamics Seminar, Toronto, Canada, October 1990.

C. M. Myllerup, J. Tonnesen and J. W. Lund, "On the Discrepancies between Experiment and Theory for a Cylindrical Fluid—Film Journal Bearing Considering Steady—State and Dynamic Characteristics," Proceedings of Institution of Mechanical Engineers *Vibrations in Rotating Machinery*, IMechE, 1992, pp. 1–6.