HALL OF FAME

A Pioneer of Ship Collision and Grounding

Professor Preben Terndrup Pedersen, Dr.Techn. h.c.

BRIEF CITATION

Preben Terndrup Pedersen was born in Denmark in 1940. He received a Ph.D. degree in Mechanical Engineering in 1969 from the Technical University of Denmark (DTU). In 1971-72, he was Research Fellow at Dept. of Engineering and Applied Physics at Harvard University, Mass. USA, and in 1973, he was visiting researcher at Det Norske Veritas, Norway.

Preben Terndrup Pedersen was appointed full professor in Strength of Marine Structures at Department of Naval Architecture and Offshore Engineering at DTU in 1973. Ship strength was at that time taught primarily based on empirical procedures, such as the ship classification society rules. These experience-based procedures were not at a level appropriate for the design of new types of ships and offshore structures. Therefore, his early teaching and research in his new position focused on introduction of first principle, rational applied mechanics, methods for structural design of ships and ocean engineering structures.

Professor Pedersen's expertise is on wave-induced loads and response of ships and offshore structures, ship collisions and grounding, and risk analyses related to maritime activities and major bridges crossing waterways. The main goal of Dr. Pedersen's work on collision and grounding analysis has been to identify the most economic risk control options related to prevention and mitigation of collision and grounding events.

EARLY TIMES (1940-1973)

Preben Terndrup Pedersen was raised in a small village in Jutland, Denmark. As a boy Preben, spend much time in his father's automobile repair shop. Another interest of his was aeroplanes.

After high school, he decided to pursue his interest for mechanics and study engineering. He moved to Copenhagen in 1960 and started as a mechanical engineering student at "Den Polytekniske Læreanstalt", which now is known as the Technical University of Denmark (DTU).

After obtaining his M. Sc. in 1966, Preben did his one-year military service working at the Danish Defense Research Board. Here his main job was to perform shock and vibration measurements and performance analysis of fast military gas turbine torpedo boats and some new Danish frigates. This became a very interesting period, which turned his interest towards naval architecture.

After completing military service, Professor Frithiof Niordson at the Department of Solid Mechanics at DTU, asked Preben to become his scientific assistant. The job was to help Prof. Niordson with his computer calculations and to teach solid mechanics, eigenvalue theory and theory of vibrations for M.Sc. students.

The workload was such that it allowed Preben at the same time to study for a Ph.D. The topic was stability and vibrations of gas and steam turbines. In 1968 Preben was bold enough to submit a proposal for a presentation on his thesis topic to the 12th International Congress of Applied Mechanics held at Stanford University in California, USA. Much to his surprise, his paper was selected as a sectional lecture[1]. This presentation became his first international lecture. Later he applied the tools he developed[2,3] also for analysis and design of propeller shafting.

After receiving his Ph.D. degree, he became first an assistant and thereafter an associate professor at the Department of Solid Mechanics at DTU and taught strength of materials, eigenvalue theory, and theory of vibrations until 1972.

Upon an invitation from Prof. John W. Hutchinson, Preben and his wife Annelise left Denmark. Annelise to study food science at MIT and Preben to become a research fellow at Department of Engineering and Applied Physics at Harvard University, Cambridge, Mass. USA. Besides Prof. John W. Hutchinson, Preben had the good luck to work with Profs. B. Budiansky and L. Sanders. This group was well known for their work on shell structures and buckling of imperfections sensitive structures. To learn from these professors it was prudent to study buckling of stiffened cylindrical shell structures[4,6] of a type used by NASA for their space rockets.

During his stay in Cambridge, Preben was offered a position as full professor in strength of large complicated structures at the Department of Naval Architecture at DTU. To prepare himself for this position he decided to spend some time as a visiting researcher at Det norske Veritas in Oslo, Norway. Here he became involved in the structural analysis of Liquefied Natural Gas (LNG) carriers of the Moss Rosenberg spherical tank design. With background in his research at Harvard University, he identified a failure mode due to partial tank loading, which had not been taken into account during the initial design phase of these advanced vessels.

After an eventful time in Norway, Preben Terndrup Pedersen could return to Denmark and take up his position as professor in strength of marine structure, 32 years old. At that time, he was the youngest full professor in Denmark.

PROFESSOR AT THE TECHNICAL UNIVERSITY OF DENMARK (1973-)

Shipping and shipbuilding has always been important for the economy in Denmark. Therefore, naval architecture is a very old subject at DTU. The first chair was established in 1897.

When Preben joined the Department of Naval Architecture at DTU in 1973, the department had two full professors and three associate professors. The other full professor was Prof. Sv. Aa. Harvald within Ship Design. To strengthen the new subject, marine structures, Preben Terndrup Pedersen hired the young Dr. Jørgen Juncher Jensen, as assistant professor. Dr. Jensen became an excellent and much valued colleague to Preben and advanced later to become full professor at the Department.

Ship structures based on first principles.

It has been a general guideline for Prof. Pedersen's research to contribute to the development of rational design tools based on first principles for the design of ship structures[12,72,83]. Here three examples shall be mentioned.

To follow up on his practical experience from his time at Det norske Veritas in Oslo, Prof. Pedersen's first contribution to direct design of critical marine structural elements concerned design and development of new classification rules for spherical tanks for ship transportation of Liquefied Natural Gas (LNG)[7,8,9]. This research was focused on imperfection sensitive buckling behavior of the containment shells in partial tank loading. Buckling of thin-walled shell structures is often a challenge for marine structures. Therefore, an analysis procedure was developed for bifurcation and initial post-buckling behavior of shells of revolution with arbitrary curved generators (tensor formulation) and with an arbitrary variation of the thickness of shells, subjected to non-axisymmetric loading. This procedure can be used to determine the imperfection sensitivity for LNG spheres, other thin-walled maritime structures, and containment shells for nuclear power plants[33].

To improve the structural design of ships subjected to wave induced loading Dr. Jensen and Prof. Pedersen developed a quadratic strip theory for ships with flexible hull girders, which can be applied in the frequency domain[11,13]. This procedure is well suited for short and long term probabilistic prediction of wave induced hogging and sagging bending moments and shear forces in ships with large bow flare, such as container vessels[32,52,80]. The results from this research became part of the decision to develop new International Association of Classifications Societies (IACS) rules for wave-induced loading of ships. The research was continued to take into account dynamic hull girder response due to bottom slamming which was shown to increase the extreme loading with up to 30% [77,78]. The results have been included for practical application in an ABS guideline for ship design.

To gain insight into the crucially important torsional - bending behavior of ships with large deck openings, such as containerships and some bulk carriers, Pedersen developed a new calculation procedure based on the solution of a set of coupled differential equations, which describe the behavior of thin-walled beams with slowly varying properties[15,16,17,18,28]. These differential equations take into account effects such as warping and deflections due to shear and rotatory inertia. The abrupt changes in cross-sectional properties, which occur at the transitions between open and closed parts of the ship hull and where deck beams are situated, were introduced as discontinuity conditions. Ultimate strength of containership hull girders was also studied[66]. Several Classification Societies used this theory to analyze new generations of containerships.

Prof. Pedersen has had good opportunities to test his applied mechanics based tools on important industry projects. After the sinking of the Ro-Ro Passenger Ferry, Estonia, in 1994, Prof. Pedersen participated in an IMO committee for analysis of the strength of bow visors.

When the US Office of Naval Research in 1995 wanted to establish a strategic plan for their future research Professor Pedersen was asked to become member of their board for “Future Directions” This influential committee work was completed by a publication in 1998[54].

As the only person from the academic world, he was from 2002 member of the External Review Group advising Lloyds Register of Shipping, American Bureau of Shipping and Det Norske Veritas on the new Common Tanker Scantlings rules, which took effect 2006.

As a long time technical advisor to A. P. Møller – Mærsk he was strongly involved in the structural design of Emma Maersk which was the first container ship in the 15 000 TEU class of eight launched from Odense-Lindø Shipyard in 2006. She and her seven sister ships were then for some years the largest container ships constructed. These ships had to be designed based on the developed mechanics based tools since they were outside the range of the current classification rules.

Structural design of pipelines and jack-ups

Parallel to work on ship structures Prof. Pedersen has contributed with mechanics based procedures to the development of the design basis for some offshore structures. This research was inspired by advisory work for A.P. Møller – Mærsk’s offshore activities. Here two research areas shall be mentioned.

Laying of pipes in the ocean is a delicate process where it is important to monitor bending stresses near the touch down point to avoid local buckling of the pipeline, which in turn can lead to running buckling. Prof. Pedersen has developed a widely used procedure to analyze the equilibrium form of a pipeline or a cable suspended between the ocean floor and a laying barge or stinger[5,10,19]. The governing non-linear boundary value problem is transformed into a non-dimensional form such that the a priori unknown suspended length acts as a scaling parameter. The numerical solution is then based on simple successive integrations.

He has also developed tools to determine buckling criteria for pipelines subjected to a combination of bending moments and external pressure.

For already installed buried, hot, inter-field pipelines, Prof. Pedersen participated in the development of a new procedure for design against upheaval buckling[20,21,22,24]. This procedure has been extensively applied by the industry.

To improve the design criteria for leg stresses and overturning of jack-ups he has been part of the development of new analysis procedures for derivation of dynamic wave-induced response of large, flexible jack-up structures [23,25,26,27].

Probability and mechanics of ship collisions and grounding

Prof. Pedersen has been particularly interested in the development of rational tools for design against ship collision and grounding risk.

Accident statistics show that for maritime structures collision and grounding events are the most frequent causes of serious accidents at sea. Consequently, these accidents are the most important elements in any risk summation procedure for these structures.

The main purpose of risk analysis is to ensure that large accidents are low enough to be acceptable to users, the public and the relevant authorities. Of course, at the same time the risk acceptance criteria must allow an economic construction and operation. It is not possible to predict or extrapolate the likelihood of future rare events such as ship collisions from similar events elsewhere. The best we can do is to use risk evaluation models. For this reason, Prof. Pedersen has initiated and performed research on development of comprehensive, applied mechanics based risk evaluation tools for collision and grounding analyses. He has outlined a probabilistic procedure by which these tools can be used by the maritime industry to develop performance-based rules to reduce the risk associated with human, environmental and economic costs of collision and grounding events[34, 46,61,67,79].

Within this relatively new research area, Prof. Pedersen has contributed to development of mathematical models for:

- Estimation of the probability of ship-ship collisions[41,62], grounding events, ships collisions against offshore structures, and ship collisions against bridges.
- Calculation of the external dynamics, i.e. the energy released for crushing and damage of ship structures during these accidental events taking into account hydrodynamic forces acting on the floating structures[40,76].
- The internal mechanics, i.e. estimation of the resulting structural damage caused by ship collision events[42,63].
- Analysis of the survival conditions of the damaged vessels and offshore structures[64,65].

One of the benefits of the methods developed for evaluation of the probability of ship-ship collisions and ship grounding is that they make it possible to compare various navigational procedures and routes by assessing the relative frequencies for collisions and groundings[55]. Knowing the probability of ship-ship collisions in a given area, rational decisions can be made on the best-suited geographical sites for deployment of clean up and rescue vessels.

Prof. Pedersen's work on external dynamics have been focused on development of analytical methods to determine the energy released for crushing and impact impulse associated with ship-ship collisions, ship collisions with offshore platforms or wind farms, and ship collisions with bridges[60]. Comparisons of these closed form procedures with comprehensive simulation results as well as a large number of experimental results have shown that good agreement can be achieved[86].

When the probability of a collision and the probabilistic distribution of energy released for crushing of the striking and the struck vessels are known, the next step in a rational collision analysis procedure is to determine the resulting distributions of structural damages to the ships involved. For application in design, the main purpose of the internal mechanics analysis is to establish simplified analytical methods for calculating the force-penetration curves and the absorbed energy-penetration relationships related to analyses of ship-ship collisions. Prof. Pedersen participated in derivation of a number of efficient tools for crushing analyses together the friends and colleagues: Prof. Y. Bai[30], Prof. J. Paik[36,39,44,45,49], Dr. Y. Yamada[71,73,74,75], and Dr. S. Zhang[57,69,84,85,87,88,] who all spend extended periods of time with Preben at DTU.

The developed probabilistic tools make it possible to estimate structural damage distributions for specific ships on specific routes. Together with historical data, this knowledge are used by IMO for damage stability rules[48] and for requirements to ship longitudinal strength in damaged conditions[38].

Prof. Pedersen has carried out several studies of the mechanics of grounding on flat hard bottoms or sandy beaches[31,43,59]. He has shown that the initial kinetic energy of the vessel will be spent on an initial inelastic impact phase, on lifting the ship and on friction between the ship and the sea bottom. The derived model has been validated by model scale as well as full-scale experiments[37,50]. Grounding on relatively flat sea bottoms will normally not lead to significant damage to the inner bottom of the vessel[35,51]. However, due to the lifting of the vessel, possibly in combination with additional hull girder loading due to a change in tide and wave action, this type of grounding can easily cause excessive hull girder shear loads and bending moments[38,47,53].

Similar models and tools have been applied to risk based design of offshore structures[25,70] and large bridges placed in seas with heavy ship traffic.

For many bridges, an important accidental load is ship collisions. Accidents have occurred where ships have collided against bridge piers and bridge girders such that the bridge collapsed and people travelling on the bridge killed. In addition, ship – bridge collisions often lead to disruption of the traffic on the bridge for extended periods. Such traffic disruptions can have severe economic consequences for the society.

The building of a bridge crossing a major waterway may also influence the ship traffic pattern by concentrating the traffic in new shipping lanes and introducing new navigational obstacles, the result being that the navigational conditions can become more difficult and lead to a higher probability of ship-ship collisions and ship grounding accidents in the vicinity. Therefore, an important design criterion for the bridge should be that the navigational span of the bridge is so large that ship collisions occur only because of navigational errors or technical failures on board of the passing vessels, and not because of increased navigational difficulties. The objective of Prof. Pedersen's work has been to present a probabilistic risk model for estimation of the operational risk associated with ship collisions for bridges over navigational channels and to give guidance to bridge design[56,68,81,82,89].

To facilitate the structural design of piers and pylons against bow impact, design formulas were derived for ice- strengthened ships[29,58] that have been adopted as design forces by EUROCODE. Later similar expressions have derived for ships without ice-strengthening[89].

Prof. Pedersen's work on ship collision and grounding events has been widely used in industry. Preben worked as adviser on risk analysis for The Great Belt Link during the building period 1988 to 1999 and continued as a consultant on the regular updates of the risk analysis[58,59]. The Great Belt Bridge was for a short period the longest suspension bridge in the world. He was advisor on risk management for the Oresund Link between Denmark and Sweden and he was advisor on risk management on the feasibility study for the Fehmarn Belt Link between Denmark and Germany. Since 2014, he has served as an expert within safety philosophy in connection with the Fjord Crossing Project E39 in Western Norway.

Prof. Pedersen was member of a technical committee for evaluation of the stability and procedures for salvage of the wreck of the grounded and subsequently capsized cruise vessel Costa Concordia in Italy in 2012.

He has been pioneering in establishing an international cooperation around his research field through the International Conferences on Collision and Grounding of Ships (ICCGS) held in San Francisco, USA in 1996; Copenhagen, Denmark in 2001; Tokyo, Japan in 2004; Hamburg, Germany in 2007; Helsinki, Finland in 2010; Trondheim, Norway in 2013; Ulsan, South Korea in 2016, and in Lisbon, Portugal in 2019.

ADDITIONAL INFORMATION

Prof. Pedersen's research is channeled to the research community through several textbooks and scientific papers. In nearly half a century, he has been active in International Ship and offshore Structures Committees (ISSC). His knowledge is passed on to the maritime industry through executive positions in research institutions and advisory roles as well as consulting jobs on specific issues, not least concerning collision and grounding hazards.

Preben Terndrup Pedersen is member of the Danish Academy of Technical Sciences, Foreign Member of the Chinese Academy of Engineering (CAE), Foreign Member of the Norwegian Academy of Technical Sciences, Foreign Member of The Norwegian Society of Sciences and Letters, and appointed "Thousands of People Plan of China" foreign expert, and Strategic Scientist at Wuhan University of Technology, China 2016-2021.

He has been chairman of the board of directors for IPU, member of the Danish Patent Appeal Board, the Board of Directors of FORCE Technology, and Chairman of Myhrwold's Foundation and of the Otto Mønsted Foundation

In 2010, Preben Terndrup Pedersen was awarded the Doctor Honoris Causa degree from the Norwegian University of Science and Technology for contributions to research within marine structures,

In 2006, Prof. Pedersen was awarded the Davidson Medal from the Society of Naval Architects and Marine Engineers, USA, for outstanding scientific accomplishment in ship research. In 2009, he was awarded the Alexander Foss Gold Medal for achievements within technical sciences from the Technical University of Denmark and the Danish Maritime Price for contributions to innovation and growth of the Danish maritime sector. In 2010, he received the Lifetime Achievement Award for Maritime Academics at ShipTek, Dubai, and he received the Confederation of European Maritime Technology Societies (CEMT) 2010 Award for significant contributions to European shipbuilding.

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