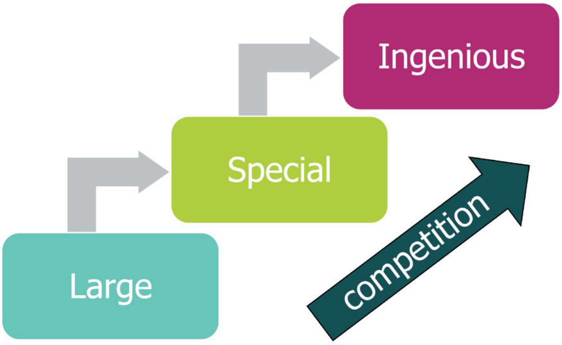
Prof.dr.ir. Miroslaw (Mirek) Lech Kaminski

Ingenious Ship and Offshore Structures

Inaugural Speech 5 October 2011

Faculteit Werktuigbouwkunde, Maritieme Techniek en Technische Materiaalwetenschappen



TU Delft Delft University of Technology

Challenge the future

Ingenious Ship and Offshore Structures

Inaugural Speech

In verkorte vorm uitgesproken op 5 oktober 2011
Ter gelegenheid van de aanvaarding van het ambt van
hoogleraar Ship and Offshore Structures
aan de faculteit van Werktuigbouwkunde, Maritieme Techniek
en Technische Materiaalwetenschappen
van de Technische Universiteit Delft

by

Prof.dr.ir. Miroslaw (Mirek) Lech Kaminski

to my son Marcin

Mijnheer de Rector Magnificus, leden van College van Bestuur
Collegae hoogleraren en andere leden van de universitaire gemeenschap
Zeer gewaardeerde toehoorders, Dames en heren,
Ladies and Gentlemen, Panie i Panowie

Foreword

Look at the beauty and diversity of these ingenious ship and offshore structures! They are ingenious in the sense that they are cleverly designed and involve new ideas and methods. Ship and offshore structures, or 'marine structures', are complex engineering systems that contribute to the prosperity of society. Among other things, we use them for transporting goods, for pleasure, for security and for exploring and exploiting natural resources, both in and under the oceans.

Figure 1. Ship and offshore structures[1, 2, 3, 4, 5, 6, 7, 8]

The longest ship I am showing is the Prelude of Shell. She is being built by a consortium involving Samsung Heavy Industries (SHI) and Technip and will be the biggest mono-hull ship ever built.

Just how big is the Prelude? Let me show you by way of a comparison. The building we are in right now, "De Aula" of TU Delft, was built of pretensioned concrete, in the brutalism style, and was completed in 1968 following 10 years of construction work.[9] It is approximately 110 metres long, 60 metres wide and 20 metres high. Its base alone is the size of a football field. To give you an idea of just how big the Prelude is, she could volumetrically accommodate 30 De Aulas!

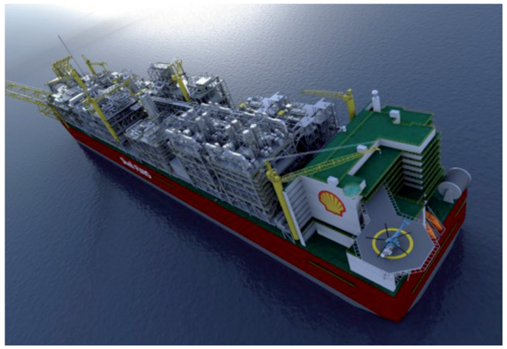


Figure 2. The FLNG Prelude of Shell.[6]

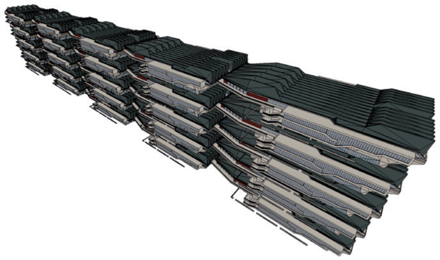


Figure 3. Illustration of the size of the FLNG Prelude - five columns and five rows of "De Aula".[10]

This illustration shows that it would take five rows and five columns of De Aulas to cover the Prelude's side view. I will return to the Prelude later, as she is the first of her kind and an ingenious example of Floating Liquefied Natural Gas (FLNG) technology.

By the way, Professor Hans Nibbering, who supervised my PhD thesis[11] here at Delft, delivered his inaugural speech 45 years ago.[12] In that speech, he also compared De Aula with the largest ship at that time. The number of De Aulas that fit into the largest ship then was "only" four.

The smallest structure I will be showing today is the fast ship, the Interceptor 1102, of Damen. One hundred and fifty thousand of these would fit into the Prelude. The Interceptor is built of glass and carbon fibre-reinforced plastic and has a maximum speed of 57 knots (105 km/hour). This speed is much higher than the speed of the Prelude, which is practically zero given that she will be permanently moored to the sea bed.

Figure 4. Interceptor 1102 of Damen (video).[2]

These two examples show that marine structures come in a diverse range of sizes, shapes and speeds and are made from a wide variety of materials. Many engineering and non-engineering fields are involved in their creation. My field is ship and offshore structural engineering, which deals with the analysis and design of hulls and other structural elements that support functional loads and resist environmental loads in such a way that enable marine structures to safely fulfil their functions.

Figure 5. Severe sea conditions (video).[13]

This video shows the severe sea conditions that some marine structures have to resist. Note the stochastic and cyclic character of wave surface. These severe conditions are important for considering structural instantaneous failures, such as fracture and buckling.

However, as this video shows, marine structures spend most of their time in benign sea conditions, which significantly contributes to the fatigue failure. The reason for this is that a large number of stress cycles of a moderate range is more fatiguing than a small number of stress cycles within a large range. Therefore, the benign sea conditions shown here, which were deliberately searched for in the Valid JIP[14], aiming to validate of fatigue design methodology of USCG cutters, are equally important and cannot be disregarded.

Figure 6. Benign sea conditions (video).[14]

Some of the other engineering fields that border the field of structural engineering are production technology, hydrodynamics, design, material science, cost engineering and mechanical engineering. The final design of a marine structure is a compromise between the different and often contradictory requirements that these disciplines claim. My colleague and designer, Professor Hans Hopman,[15] investigates and educates the best ways to achieve this compromise. Marine structural engineering is most closely linked with hydrodynamics, which estimates the loads that act on marine structures. Research and education in this field is being carried out by my colleague, hydrodynamics Professor René Huijsmans.[16] Finally, there is a very strong link between marine structural engineering and ship production. For example, material and fabrication factors, such as welding imperfections, affect a structure's load-carrying capacity.

In my speech, I will address the question of why marine structures should be made "ingenious" and how this can be achieved.

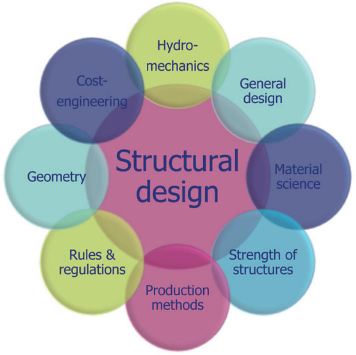


Figure 7. Some engineering fields that border the field of marine structural engineering.

Cooperation versus competiveness

Cooperation and competitiveness are natural survival mechanisms, and they apply to humans as well as the organisations we form. Are there any other such mechanisms? Tolerance, perhaps? Is tolerance not a form of passive cooperation? While questions such as these should probably be left to sociologists rather than engineers, what I do know is that shipyards, operators of marine structures and universities do cooperate and compete, both internally and externally, on national, regional and global levels. Here you can see an example of simultaneous cooperation and competition. Let me start by providing some examples of cooperation that are relevant for marine structural engineers.

Figure 8. Simultaneous cooperation and competition.[17]

The International Ship & Offshore Structures Congress [18] (ISSC) is a forum for exchanging information among invited experts who undertake and apply marine structural research. Every three years since 1961, ISSC members have voluntarily produced between 10 and 20 detailed reports that review and evaluate research in progress; disseminate results from recent investigations; identify areas requiring future research; and suggest improvements in design, production and operations procedures. These reports are public and the last 16 reports from ISSC 2009 in Seoul, South Korea, are accessible on the ISSC's website. [18] These reports are a key source of information for researchers, engineers and students. It is clear that marine structural engineers can organise themselves and keep their organisation flourishing for many years. The next ISSC congress, which is being held in Rostock in 2012, is being organised by my colleague, Professor Wolfgang Fricke from the Technical University of Hamburg Harburg (TUHH). I have contributed to the ISSC since 1988. I currently represent the Netherlands in the standing committee, with my main role being to assure ISSC's continuity, productivity and relevance.

I would also like to mention another outstanding organisation of ship structural engineers, the Ship Structure Committee (SSC).[19] This American interagency research and development committee for safer ship structures is open to experts from other countries. The mission of the SSC is to enhance the safety of life at sea, promote technology and education advancements in marine transportation, and protect the marine environment. The SSC achieves this by advocating, participating in and supporting cooperative research and development in structural design, life-cycle risk management of marine structures, and production technologies.

Figure 9. Examples of cooperation networks relevant for marine structural engineers and students.

Furthermore, the cooperation is stimulated by professional networks such as the Dutch association for engineers (KIVI NIRIA) and its Maritime Technology[20] (Martec) and Offshore divisions. The networking events of these groups, including lectures, facilitates the exchange of knowledge between structural and other engineers. As of this year, I have been given the honour of chairing the Martec division.

Joint Industry Projects (JIPs) are an outstanding example of cooperation. As I will show later, all research examples in marine structural engineering are from JIPs. Within a JIP, various stake-holders, including industry, universities, research institutes and governmental organisations, cooperate to solve an emerging problem that requires some degree of fundamental and/or applied research. Examples of Dutch marine stakeholders include Allseas, Bluewater, Damen, Gusto MSC, Heerema, Huisman, IHC, Keppel Verolme, the Maritime Research Institute Netherlands (MARIN), Royal Netherlands Navy, Scheepsbouw Nederland, Shell and TNO. The major player in initiating JIPs is MARIN,[21]

where I previously worked for 11 years. The international stakeholders participating in JIPs include class societies, such as the American Bureau of Shipping, Bureau Veritas, Nippon Kaiji Kyokai, Det Norske Veritas, Korean Register and Lloyd's Register; oil and gas companies like Total, Chevron and Petrobras; shipyards like SHI, Hyundai Heavy Industries - HHI, Daewoo Heavy Industries and Kawasaki Heavy Industries; technology providers like GTT; and ship operators such as USCG.

Research at Delft University of Technology in the field of marine structural engineering has a long tradition. In the 1970s and '80s, the Ship Structure Laboratory (SSL) flourished. The laboratory was made famous around the world through the research of Professor Hans Nibbering on the effects of shock loading, low temperatures and corrosive environment on fatigue and fracture.[22] At that time, the SSL had a 35-strong staff and had a fatigue testing rig with a 1000-ton capacity. Unfortunately, the SSL was dismantled seven years ago. Today, my subsection - Ship and Offshore Structures (S&OS) - has two associate professors, Xiaoli Jiang and Theo Bosman; and two PhD students, Hannes Bogaert and Henk den Besten, whom I supervise together with Professor René Huijsmans. Two other PhD students, Francesco Radaelli and Reza Karimi, will hopefully join the S&OS very soon. I will refer to their work later. Our vision is to become a key global player in linked education and research in the field of ship and offshore structures. Our mission is to provide answers to the complex questions that emerge in the design and operation of ship and offshore structures by carrying out fundamental and applied research in combination with academic education.

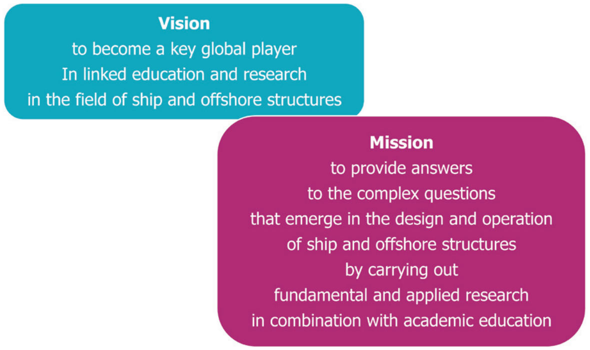


Figure 10. Vision and mission.

The question for me is how to achieve this, and I will answer that question later on in this presentation. What is certain is that we have no unique rigs for structural testing, which means that we must invest in new testing rigs and cooperate with other laboratories like the Stevin Laboratory and the laboratory of the Structural Dynamics of The Netherlands Organisation for Applied Scientific Research (TNO). Also, the in-service measurements, if required, would need to be carried out in cooperation with groups such as MARIN or TNO-SD. I will describe the investment that is required later on.

European shipyards cooperate in the Community of European Shipyard Association[23] (CESA). This organisation represents 16 national associations, covering more than 300 shipyards that produce, convert and maintain merchant and naval ships and other hardware for maritime applications. Each year, shipyards invest approximately 10 percent of their turnover in civil production in research and innovation. European yards are typically quite small in size. The world's largest shipyard, HHI, has a higher output, in terms of tonnage, than Europe's 20 largest yards combined. CESA provides input for the formulation of the European Union's strategic maritime innovation agenda.[23] The Netherlands is represented in CESA by the Holland Shipbuilding Association[24] (Scheepsbouw Nederland), which has also formally assured and sponsors my position. Another platform is the Maritime Knowledge Centre (het Maritiem Kennis Centrum[25] - MKC), which coordinates cooperation between the Dutch maritime research institutes (MARIN, TNO and KIM - Royal Netherlands Naval Institute), TU Delft and the marine industry.

The final example is the governmental stimulation programme, the Maritime Innovation Programme[26] (MIP). In fact, this programme had to be prepared by the industry, research institutes and TU Delft, which is no different from preparing a new programme. The entire Dutch marine sector and other sectors have been cooperating recently in order to advise the Dutch government on stimulating 10 of the top Dutch sectors, one of which is water.[27] The subject of ingenious ship and offshore structures fits this programme very well.

All of these cooperation efforts are actually being made to become more competitive. For example, a shipyard that cooperates on all the levels, which I described previously, must compete with national, European, Chinese, South Korean, Japanese and other shipyards in order to secure orders from operators by offering the most favourable marine structures.

The CESA report[23] said that European shipyards have competed for many years by focusing on numerous opportunities in specialised markets and by refraining from massive capacity expansions. So far, this has been successful, with the yards able to double their turnover since 2005, while keeping the output in

terms of tonnage stable. The current crisis has generated new impulses for radical thinking to adopt new designs in order to reduce operational costs. Currently, the most important factor for most operators when making purchasing decisions is the capital expenditure (capex); for example, the price of a new asset like a ship. However, operational expenditure (opex), which includes crew costs, maintenance costs, emission fees and fuel costs, is becoming more and more important because the long-term benefits of an operator depend on the balance between capex and opex.

For many years, Dutch shipyards and marine operators have been outstanding at following the specialisation route. Safeguarding this position and realising new market opportunities requires a decisive counter-action against growing competition. Specialisation alone is essential, but building and operating ingenious ships and offshore structures is the next step.

As I stated earlier, marine structures are ingenious when they are cleverly designed and involve new ideas and methods. This is the *sufficient* condition. The *necessary* conditions for marine structures to be ingenious is when they are competitive throughout their lifecycle cost (design, engineering, fabrication, operation, environment and demolition) and when they are sustainable (that is, causing little or no damage to the environment).

In concluding this part of the presentation, I would say that we need ingenious ship and offshore structures in order to safeguard the prosperity of our society.

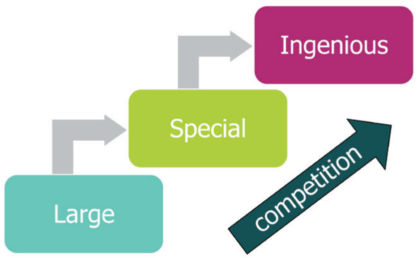


Figure 11. Counteraction against growing competition.

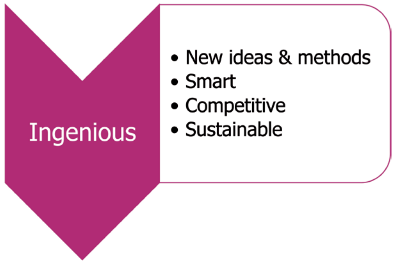


Figure 12. Definition of ingenious.

I will now answer the question of how marine structures should be made ingenious from the point of view of marine structural engineering. This aspect definitely requires research and development efforts.

Research

Marine structural engineers use a relatively small number of basic structural elements, such as plates and beams, to build up marine structures that, I showed at the beginning of my speech, can be very complex. Within the limitations imposed by other engineering disciplines, marine structural engineers design the structure in such a way that it cannot collapse under all expected loads in all expected conditions without appropriate warning. Therefore, knowledge and understanding of all possible failure modes is of crucial importance for marine structural engineers. This slide shows some basic structural failure modes. In this speech I am focusing on fatigue.

Figure 13. Basic structural failure modes.[28, 29, 30, 31, 32, 33]

As I discussed earlier, knowledge about fatigue failure is not enough to make the marine structures ingenious. For many years, I have been providing designs and proposing new ideas and methods that make marine structures less expensive, as well as methods that minimise their operational cost.[34, 35] I will continue research in this direction. Before describing my specific present and future research, let me first discuss the various lifetime stages of marine structures. In my opinion, ingenious marine structures can be obtained, on one hand, by integrating design, production, operation and maintenance, and on the other hand by implementing smart structural solutions.

This slide shows examples of methods and actions that ensure the desired fatigue lifetime of marine structures at their different lifetime stages. My research ambition is to cover all these stages. The S&OS team is already involved in eight JIPs. I will now discuss different present and future research areas for each design stage and make reference to some of these JIPs.

Preliminary design	• First principles, empirical methods, experience • Keep the overall stress level low
Design/ Engineering	• Rules and direct calculations methods • Avoid stress risers, use adequate details
Production	• Production procedures and quality assurance • Remove unacceptable defects
Operation	• Inspection, repair & maintenance procedures • Use advisory monitoring systems
Demolition	• Cradle to Cradle (C2C) methods • Use sustainable materials

Figure 14. Lifetime stages of marine structures and associated methods and actions ensuring sufficient fatigue lifetime.

Monitas	• Advisory monitoring system
Vomas	• New fatigue design method
CrackGuard	• Affordable wireless crack guarding system
Adhesion	• Adhesive bonding in ship structures
Renewable	• Renewable energy from waves
Flight	• New materials in conceptual design
Valid	• Validation of fatigue design methodology
Sloshel	• Scaling of sloshing impacts

Figure 15. Joint Industry Project with involvement of S&OS.

Preliminary design

Early design decisions are crucial for the structural performance of marine structures. Stretching the hull of a sea going ship in the vertical direction by 10 percent (that is, enlarging the distance between the strength deck and the bottom without changing the cross-sectional area of the hull) extends its fatigue lifetime by approximately 25 percent! It may be surprising but, to my knowledge, there is only one preliminary fatigue design method available in the open literature.[36] The earlier the fatigue considerations are taken into account in the design process, the easier it is for the marine structural engineer to ensure a sufficient fatigue lifetime. It might be too late to carry out the fatigue check when the design process is well advanced and the global scantlings are fixed because the global stress level might appear too high, even for smart structural details. Therefore, the first research area is:

- Preliminary design methods for estimating fatigue lifetimes of marine structures.

Design and engineering

One example of an engineering method is the total stress method that PhD student Henk den Besten[37] is developing within the Vomas JIP led by Damen. To date, this method has been developed for fast aluminium ships based on theoretical investigations, including the Linear Fracture Mechanics, and available experimental data. At the moment, the method is being validated using dedicated small-scale, large-scale and full-scale tests. After validation, the applicability of the method can easily be extended to other metallic structures. The method has the potential to significantly improve our ability to predict the fatigue lifetime of welded structural details. Instead of only using the surface stress, the method uses the distribution of stresses over the whole plate thickness. This distribution is obtained as a super-position of different stress components, such as the membrane and bending stress components. Furthermore, the method accounts for many fatigue crack growth-affecting factors, such as weld geometry and mean stress. The two figures shown here illustrate how the conventional experimental data (shown on the left) is reduced to one master data set (shown on the right) using den Besten's method. This data set includes weld toe- and weld root-induced fatigue failures for different joint types. The figures show, respectively, the number of cycles to failure (N) in function of the far field stress range ($\Delta\sigma_t$) and the total stress parameter (S_t) proposed by den Besten.

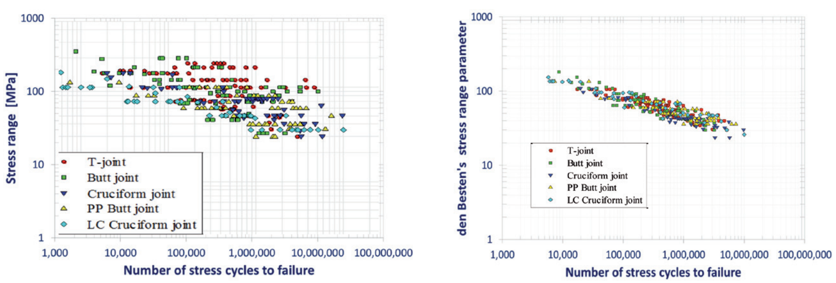


Figure 16. Conventional (left) and den Besten's (right) fatigue test data.[37]

The equations that den Besten proposes are relatively extensive and would require a few pages to describe completely. The challenge now is to implement this method in the Finite Element Analysis (FEA) post-processor in such a way that the fatigue lifetime of all welds, which are not modelled, is checked and visualised automatically. I will illustrate this challenge on the example of a T-joint shown in this figure, which also shows an experimentally determined stress field using the digital image correlation technique and the stereoscopic principle. The joint consists of two plates connected by two welds. The joint has six likely crack paths, each of which must be analysed separately. In the FEA model, the plates are modelled by shell elements, which means that the joint is represented by only one line. It is clear that such FEA model does not include information about the welds, misalignments and the extent to which the welds are penetrated. This information must be added to the FEA model. A 100-metre long ship contains approximately 30 kilometres of welds. Accordingly, this process could easily become tedious work and could therefore prevent widespread use of the method. Hence, it must be done in a smart way by proper grouping of elements and the use of inherence mechanisms. Therefore, the next research area is:

- Smart post-processing of Finite Element results for fast estimation of fatigue lifetimes of welded joints in marine structures.

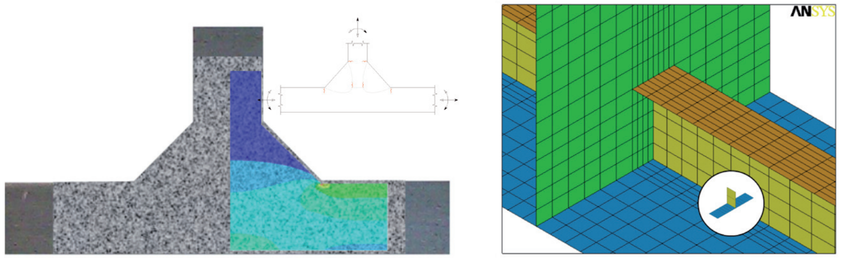


Figure 17. T-joint aluminium specimen (left); likely crack paths (middle) and the FEA model (right).[37]

At the start of my presentation, I showed videos of ships in continuously varying sea waves. The actions of these waves produce continuously varying stresses in ship structures. Predicting these stresses requires integrated hydro-structural tools. It may surprise you again but, to my knowledge, there are only few integrated hydro-structural tools. These tools are still under development, often require manual actions and are limited to, for example, linear systems, zero-forward speed or head seas, and stop at calculating stresses without checking structural failure modes such as fatigue. This video shows the calculation results of a hydro-structural tool for a container carrier in irregular head waves. The changing colours of the ship's hull indicates the changing values of structural stresses.

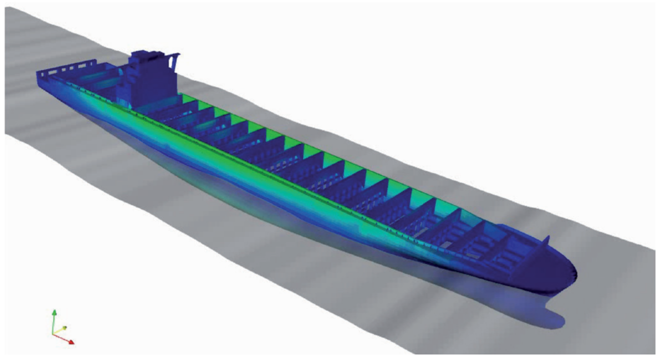


Figure 18. Wave-induced stresses in a container vessel (video).[38]

Following this discussion, I conclude that the next research area is:

- Smart integrated hydro-structural tools for structural failure analysis of marine structures

The methods for calculating structural failures, such as fatigue, need to be revisited in order to benefit from recent computational potential. There is a mismatch between implemented methods and available data. For example, present hydro-structural methods can correctly reflect phase differences between different loading components. This is crucial for adequately evaluating fatigue failure under multiaxial loading. For example, the fatigue life for the non-proportional multiaxial loading (out-of-phase) characterised by changing principal stress directions is twice as low as proportional multiaxial loading (in-phase) that is characterised by constant principal stress direction.[39] Therefore, the next research area is:

- The effects of multiaxial loading on fatigue behaviour of structural details in marine structures.

A special testing machine is needed in order to investigate fatigue failure of structural details subjected to multi-axial loading, and this means an investment. I claim this investment because the experimental research on fatigue of joints subjected to multiaxial loading will improve our ability to better predict the fatigue lifetime of ship and offshore structures.

Further, this research will give an impulse that we can build upon in order to become a key global player in linked research and academic education.

Another research area is associated with deep-sea exploration and exploitation. It is surprising to note that we know much less about the behaviour of structures and their components in deep seas than those on the Moon. Two-thirds of the Earth's surface is covered by oceans. However, 85 percent of the oceans are between 2000 and 6000 metres deep and is barely being explored or exploited. The main reason for that is that these watery depths are a world of darkness, high pressure levels and cold. Ocean temperatures fall sharply with depth until around 4°C, and the associated water pressure ranges from 200 to 600 bars. The shortage of minerals onshore and recent developments in new materials and positioning systems have made ultra-deep sea exploration and exploitation more and more attractive.

Generally speaking, the behaviour of materials and structural components has been predominantly investigated at ambient hydrostatic pressures of 1 bar. These results are usually extrapolated to higher pressures by allowing for the additional stress components that result from hydrostatic pressure and considering the same failure mechanisms. However, there is evidence that material behaviour changes with increasing pressure. This leads to uncommon structural failure modes at high pressures. As early as 1946, Percy Williams Bridgman,[40] a professor at Harvard University, won the Nobel Prize in Physics for his work in high-pressure physics. One of his major contributions concerned the effect of pressure on the fracture of uncracked bodies. His experiments were basically normal tension tests that were executed in a very-high-pressure chamber.

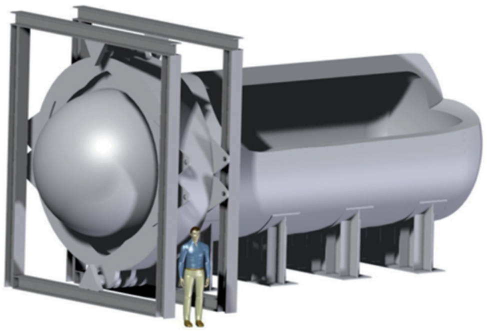


Figure 19. Concept hyperbaric (up to 600 bar) test chamber for deep-sea development.[41]

Almost all aspects of structural engineering must be revisited for deep-sea applications. This includes material fracture mechanisms, transition between failure modes, multi-axial fatigue, crack propagation, low-cycle fatigue and creep. All of these phenomena are non-linear, which means that testing of materials and structural components should be carried out at dimensions that match potential applications. Dedicated test chambers are required in order to investigate material and structural components behaviour at high pressure. I am now showing a concept of a high-pressure test chamber that is being designed by a Dutch consortium led by TNO.

The research area associated with deep sea development is:

- Behaviour of materials, structural components and systems in deep-sea conditions.

When I was working at MARIN, I built the Hydro Structural Services (HSS) team. I initiated and carried out, together with the team, valuable, large and exciting break-through research projects; namely, Sloshel[43], Monitas[44] and Valid[14]. These projects are still running and are currently run by my pupil and PhD student Hannes Bogaert, who also became my successor. I observe, with some satisfaction, that the team is growing and actively acquiring new research projects. Good luck! I see a lot of opportunities for joint research in the field of marine structures.

I will now return to the FLNG Prelude of Shell. This offshore unit produces natural gas and stores it in the liquefied state in tanks at a temperature of minus 162 degrees Celsius. At this low temperature, the steel hull would not have sufficient strength, so it is isolated from LNG by a containment system such as the Mark III[42] system of GTT, which I am showing now. The next figure is a picture taken inside an LNG tank. As you can see, it is one big volume. At some combinations of ship motions and tank filling levels, for a given tank shape and dimensions, the LNG starts to slosh and may exert high pressures on the containment system and ship structure. Sloshing is an undesired phenomenon and a designer will undertake various measures to reduce its intensity and probability of occurrence. In general, a designer will employ small-scale tests to justify his or her design. This video shows an example of such tests. In the Sloshel project,[43] we simulated the sloshing impacts in the Delta flume[45] by breaking waves on vertical concrete walls with embedded real containment systems. This video shows the tests, which are self-explanatory. Note that the impacted wall was covered by the characteristic corrugated membrane of the Mark III system and that there was an observation window adjacent to the impacted wall on the left side of the flume.

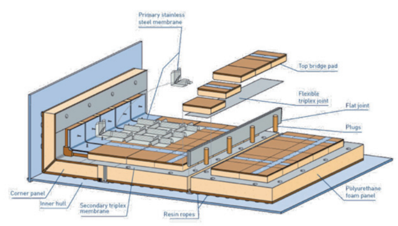


Figure 20. Mark III containment system.[42]

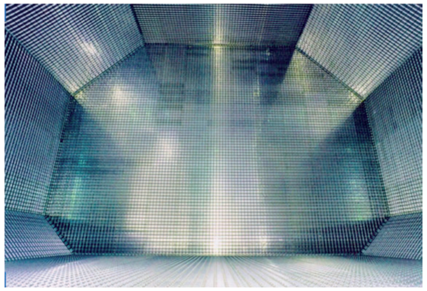


Figure 21. LNG tank with the Mark III system.[42]

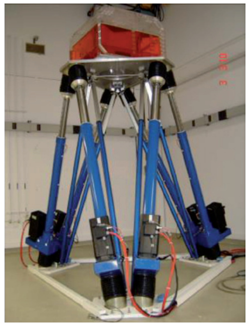


Figure 22. Small-scale sloshing tests (video).[42]

Figure 23. Sloshel tests (video).[46]

The main goal of the project was to study the hydro-elastic interaction, which required a simultaneous measurement of fluid flow, pressures and structural deformations. It was not an easy task but we succeeded because "failure was not an option!" With permission of the Sloshel project, I am showing you a close-up video of waves impacting the Mark III containment system and the simultaneous deformation of the foam of this system. One high-speed video camera, which was placed behind the observation window, shows a turbulent flow of water and air over two horizontal corrugations of the Mark III membrane. Two other high-speed cameras, placed in the wall, videoed Mark III foam covered by a stochastic speckle pattern. After the tests, two videos were processed using the previously-mentioned digital image correlation technique and the stereoscopic principle in order to obtain the foam deformation shown in a colour scale that ranged from blue to red.

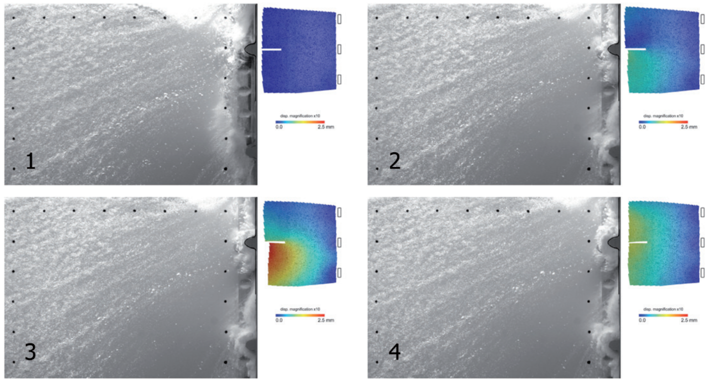


Figure 24. Simultaneous hydro-structural measurements of impacted Mark III containment system (video).[46]

The Sloshel project demonstrated that local peak pressures are not filtered out because there is a clear link between these pressures and local structural deformation. The spatial and temporal description of the sloshing pressures is yet to be investigated and this is intended to be the subject of Reza Karimi's PhD thesis. Hannes Bogaert is very close to completing his PhD thesis, which deals mainly with the scaling of sloshing impacts.

The research area associated with hydrodynamic impacts on/in marine structures is:

- Understanding impact pressures and their spatial and temporal modelling for the purpose of structural design.

Production

An ingenious marine structure must be competitive throughout its lifecycle. The challenge is to reduce production costs without having to pay extra for operational costs. An ingenious solution is to reduce both costs. A short-term cost reduction can often be achieved by subcontracting hull construction to low-wage countries. In the long term, however, this leads to knowledge erosion and the inability to supervise the production process, which can result in lower quality and increased operational costs. In my opinion, a preferable solution is to use production-friendly structural details in combination with computer-integrated manufacturing (CIM) and optimised production logistics.

I see a lot of potential in topology optimisation, which allows designers to generate optimal structures and details without specifying the structural arrangement in advance. This technique can even be applied during the preliminary design, where design choices have the largest impact on final performance. My colleague, Professor Fred van Keulen, and his team are working in this area.

In order to demonstrate the potential of this technique, I am showing you how the transverse structural arrangement of a catamaran develops during topology optimisation. In this example, which was especially prepared for this presentation, the structure is only loaded by the transverse loading, as indicated by red arrows. The selected target of the optimisation was to maximise the structural stiffness in the direction of the arrows, while using a specified amount of material.

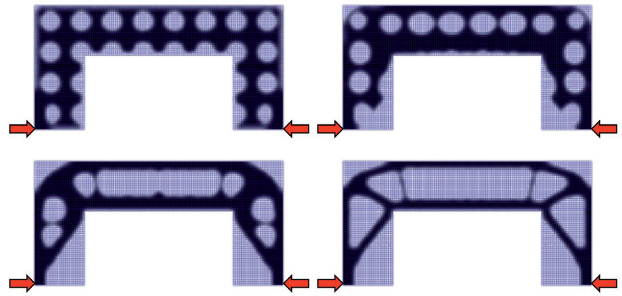


Figure 25. Topology optimisation of transverse structural arrangement of a catamaran (video).[47]

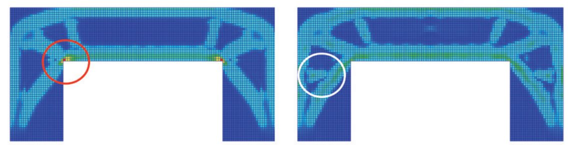


Figure 26. Results of topological optimisation, without (left) and with (right) stress constraints.[47]

This figure shows the Von Mises stresses in the optimised transverse structure. This structure shows high stress concentration, as indicated by a red circle. By introducing an additional constraint on the stresses, the topology optimisation finds a different structural arrangement without stress concentrations. In the white circles, you can see an additional structural element and an increased radius at the re-entrant corner that help eliminate the stress concentration.

In order to research and develop ingenious structural arrangements and details, I propose using topological optimisation to minimise lifetime cost, including fatigue failure criteria based on the den Besten method and manufacturing constraints. To summarise, in the field of production engineering of ship and offshore structures, I intend to focus research on:

- Ingenious structural details, such as employing topological optimisation with fatigue and production constraints.

Operations

The ship and offshore structure age during operation. However, aging is not an issue; it is all about managing the aging process. The Monitas JIP has developed a system, also called Monitas. The Monitas system presents, explains and advises on the fatigue lifetime consumption of FPSO's hulls. The advice is based on comparisons between the design and the actual fatigue lifetimes calculated by the fatigue design tool. The actual lifetime is calculated using measured data instead of the design data. The measured data includes operational settings, environmental conditions and hydro-structural response.

The Monitas system reduces operational costs because deviations from the design conditions can be identified in a timely manner and rational actions can be undertaken to secure sufficient lifetime in case it is being consumed too fast. A rational action is possible because the Monitas system identifies the factors that contribute most to faster lifetime consumption. This video shows the monthly changes of fatigue lifetime consumption predicted by the system.

Although the Monitas system is definitely a breakthrough, its methodology can be improved. This is already taking place within the Monitas II JIP, in which TU Delft participates. The Monitas methodology currently results in deterministic prediction of lifetime consumption. Francesco Radaelli is investigating how the uncertainty of this prediction can be quantified. This figure shows the envisaged result of the Monitas II system. You can see the probability distribution of forecasted structural lifetime as a function of monitoring time. The longer the monitoring period, the less spread the forecasted structural lifetime.

Figure 27. Lifetime consumption predicted by the Monitas system (video).[48]

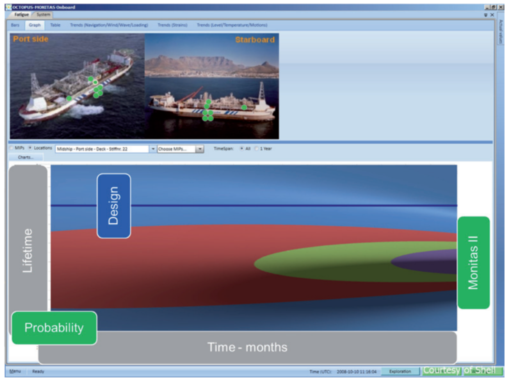


Figure 28. Envisaged output of Monitas II system.

So, the next research area is:

- Methodology of advisory hull monitoring systems for ship and offshore structures

Although various efforts are undertaken during the design, engineering, fabrication and operation stages of marine structures to avoid fatigue cracks, the operators are obliged to periodically inspect the structures for the presence of cracks. Cracks that are too long for safe operation must be repaired. Cracks of an acceptable length must be followed up during successive inspections. However, the uncertainty of crack growth rates means it is not known when the cracks will reach their critical lengths. Therefore, operators either increase inspection frequency or reduce the allowable crack length, which leads to higher operational cost. Interviews with marine operators revealed that they seek an affordable, simple and robust system to guard the length of detected cracks. Such system should only warn the operator when a crack has reached its predefined unacceptable length. The overall costs of the system should be competitive with the cost of additional visual inspection by a surveyor. The CrackGuard JIP aims to research and develop such a system.

Together with Professor Erik Puik from the University of Applied Sciences in Utrecht, I am researching the feasibility of the CrackGuard system. This video shows an experimental prototype that checks whether the selected measuring principle does work. As you can see, the prototype monitors the crack and products a message when the crack becomes critical.

The next research area is:

- Robust and affordable systems for monitoring detected cracks in ship and offshore structures

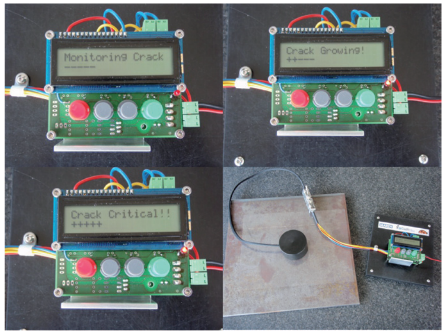


Figure 29. Experimental prototype of CrackGuard system.[49]

Finally, I also see other areas for research, such as:

- Design and engineering method to account for confused sea states
- Smart integration of heavy structural components in relatively thin hulls
- Unconventional structural arrangements for better transfer and distribution of loads
- Fatigue and ultimate strength of adhesive joints
- Smart composite structures
- Fatigue and ultimate strength of floating devices for renewable energy
- Behaviour of materials in arctic and cryogenic condition

As you may have noticed, there are enough fundamental and need-driven research areas that I have identified, and the list is certainly not complete. My experience tells me that I must make certain choices and be persistent in executing the selected research projects.

Education

Ship and offshore structure are only as good as the engineers who design, engineer, build and operate them. The industry needs engineers and the role of technical universities is to educate students so that they become engineers at either the bachelor, master's or doctoral levels. I am responsible for education in the field of ship and offshore structures at all of these levels. However, I also intend to establish contacts with secondary schools in order to inspire future students for marine technology and, specifically, for my fantastic field of engineering.

I believe that enthusiasm, professional knowledge and devotion are important elements in education. I have already given lectures for first-year BSc students on ship and offshore structures, and I have done this in the best way I could. I prepared nice PowerPoint presentations; I introduced short assignments in my lectures, for which students could earn 10 percent of their final mark by answering them correctly. I carried out simple experiments during the lectures in order to illustrate the theory; I asked students questions and I invited students to ask me questions. I underlined and repeated crucial considerations in the field. I gave students homework and discussed the solutions during the following lectures. I asked students for feedback, and I gave students my feedback. The result of all this is that I was very well assessed by the students. So, you would think that I had done my educational job very well. I have to admit that I had the same thought until the exam, which consisted of questions that checked understanding and problem-solving, separately. In two exam terms, 109 students participated, with few taking the exam twice.

Look at the exam results. Each point represents one or more students with the same result. The students above the red line passed the exam. If we disregard the few students below the blue line who did not take the exam seriously, only 58 percent of students passed the exam. This pass rate is too low and my ambition is to increase it. How do I do this? I think I have already found a solution. Firstly, let me analyse the exam results further. The figure suggests that there is no correlation between understanding and problem solving. How could this be true? Well, when you introduce a diagonal pink region, which represents students for whom understanding correlates with problem solving, something immediately happens: virtually no students who passed the exam understand the subject and did not solve the problems! This region is indicated by the blue triangle, which is practically empty. This means that if a student understands the problem sufficiently, he or she can solve the problems and pass an exam. This explains the asymmetry of exam results. Hence, the way to increase the pass rate is to increase the students' understanding of the subject. So, I have arrived at a new question, which is: how can I increase this understanding?

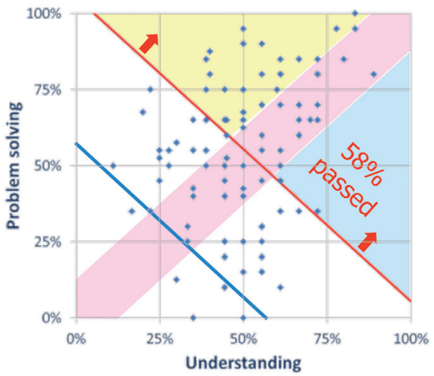


Figure 30. Relationship between scores for calculations and understanding.

I have started to research this subject further. At first, I decided to understand my students and I read a very inspiring book called "Generation Einstein".[50] I also had an opportunity to accompany offshore and dredging students on their study trip to Singapore for one week. And, of course, I have my own son, Marcin. So, the new generation is very social, involved, loyal, looks for intimacy, communicates fast and continuously, is media-smart, loves quality, can directly distinguish between authentic and fictive options and attitudes, and is business-wise. However, all of this knowledge did not help me to answer my question; particularly, because I was confused. On one hand, educational theory says that people learn more together with other people. I think this was the basis for introducing project education. On the other hand, the students told me that the project education facilitates hiding and that, in practice, only part of a group works on a project.

I found the answer to my question very recently during a lunch seminar called "Confessions of a converted teacher", and the associated workshop by Eric Mazur, professor of physics and applied physics at Harvard University. I will not repeat his method of peer instruction here, but I hope I have made you curious enough to visit his website.[51] Anyway, I am inspired!

Student associations play an important role in communication between academic staff and the students. I intend to co-operate crossly with student associations "William Froude" and "Dispuut Offshore Technology" of the maritime technology and offshore and dredging students, respectively. This is because we all have the same goal, which is to improve education. I hereby plead for full compensation of the board members of these associations by their respective departments.

Furthermore, I plan to investigate possible educational cooperation in the field of ship and offshore structures with other universities, including the group of Professor Wolfgang Fricke at TUHH, and the Centre for Ships and Ocean Structures (CeSOS) of Norwegian University of Science and Technology (NTNU) led by Professor Torgeir Moan.

Motivation

I would like to share a short anecdote. My father is a mechanical engineer and, for as long as I can remember, he was always slightly jealous of those friends of his who were surgeons. Although he worked just as hard as they did, they earned much larger salaries. So, having discovered my curiosity and eagerness to learn, my parents decided that I should become a surgeon. They knew that long and delicate fingers are very important for a successful surgeon; so, when I was five years old, they bought me a piano. I was expected to play piano as a way of exercising my fingers. However, my curiosity to discover how a piano works was so strong that I carefully disassembled the piano into its most elementary pieces - which was not an easy job - and I became an engineer! I was never punished for doing this, and I think that deep in my father's angry eyes, I saw that he was proud of his son.

Once I became an engineer in my heart, I developed my dream of becoming a professor, step by step. This started as a child, when I would play with the written exams of my father's students, and later as a student when I got to meet the great professors, Marian Kmiecik and Hans Nibbering. However, besides fulfilling my dream, my real motivation for becoming a professor is my new mission. After 35 years of continuous professional development, including many structural designs, initiating and carrying out fantastic research projects, coaching and management, my new mission is to educate outstanding engineers, while also conducting research in the field of ship and offshore structures.

Acknowledgements

I would like to thank the Dutch marine industry (Damen Shipyards Group, IHC Merwede, Bluewater, Allseas, Gusto MSC, Keppel Verolme, Huisman Equipment, Bureau Veritas, Lloyds Register, TNO, MARIN and Scheepsbouw Nederland) and TU Delft for recognising the need for academic education in the field of ship and offshore structures, and also for creating and funding my position. In this matter, I am most grateful to my colleague Professor René Huijsmans.

Very special thanks go to my family, friends and colleagues for showing me that my choice to become a professor was the right one, and to my TU Delft colleagues and students for their enthusiastic welcome at the university.

Figure 31. Enthusiasm of TU Delft students.

I would like to thank my parents, sister, brother and family for their unconditional love and support. I am mostly grateful to my dear princess, Ula, and my son Marcin.

Thank you to everyone here, and to those who have followed my speech on the web via Collegerama.
(now.tudelft.nl).

I would like to thank Henk den Besten and Paul Riem for their support during this presentation.

Ik heb gezegd.

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