Intentional Grounding of Disabled Ships - On-board and Shore based Decision Support System

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ABSTRACT: The paper presents a model to determine the consequences of intentional grounding (structural damage, rupture, potential flooding or oil spill), including further progress of damage and spill due to tidal variations and/or escalation of waves and wind. The grounding process is decoupled into rigid body motion and resistance to penetration of the bottom structure. The latter is calculated on the basis of predetermined resistance - penetration relationships for typical ship bottom structures and/or simplified methods. Degradation of hull girder capacity due to bottom damage and initial damage is taken into account. Required tug force to pull the ship off the ground is also estimated

The work is part of a project devoted to development of a decision support system, which will provide guidance to the shipmaster and the various levels of decision makers on board and on shore on how to operate a ship once a potentially critical damage has occurred: i.e. how to maneuver in critical waters with loss of propulsion or damaged maneuvering systems, how to operate / navigate to limit sea loads, such that hull damage (e.g. due to collision, grounding, overloading of degraded structure) does not propagate to a critical level for the entire ship, and, as a last resort, to assess the consequences of running the ship aground. The project is funded by the European Community under Framework Programme 6.

1. INTRODUCTION

Both historical and recent events have made it clear that ship grounding and collision represent significant hazards. This applies both with respect to loss of human lives, severe environmental consequences and economical losses. The most typical consequence of ship grounding and collision is oil spill as exemplified for instance by the Sea Empress which spilled 65,000 tons of crude oil at Milford Haven harbor, Wales, in 1996. In 1997, the Nakhodka, a Russian tanker carrying 19,000 tons of heavy fuel oil broke into two during storms in the Sea of Japan with severe environmental consequences.

Also in Norway several accidents have occurred that have caused serious public concern. In 1992 the Panama registered bulk carrier "Arisan" grounded near the famous bird nesting cliff Runde and considerable amounts of oil were threatening the island. In the fall of 2000 "Green Ålesund" capsized close to Haugesund and "John R" stranded and broke in two on Grøtøy North of Tromsø. In both cases only favourable conditions prevented major oil pollution .

A recent high profile accident is the sinking of the oil tanker Prestige off the Spanish Galicia. These events demonstrates that the risk level is not acceptable, and that public awareness of sub-standard transportation systems is increasing. The risk of massive spill or casualties constitutes a threat to sustainable development. Improvement of casualty prevention measures is therefore essential to obtain the desired level of safety at sea and protection of marine ecosystems.

If counter measures are not taken the risk associated with maritime transport especially in Northern European waters is likely increase substantially in the future. Plans are being drafted for developing large facilities in North Russia for depositing of nuclear waste from European power plants. This implies transport of such waste along Norwegian coast also during extreme weather conditions in wintertime. The expanding oil exploitation in the Barents sea is projected to increase current transport volumes from passage of one VLCC tanker per week at present, to one VLCC per day in 2007. It is evident that the exposure to oil spill from stranded tankers increases considerably. This is all the more serious as the Barents sea is one of the last unspoiled marine environment in Europe and hosts one of the world’s richest and most pristine marine ecosystems. Arctic areas are particularly vulnerable to pollution, due to local climatic conditions and the fragility of the food chain mechanisms. A large oil spill could cause dramatic consequences to the wildlife in this area, both seabirds, mammals and fish stocks.

The adoption of double side hulls in oil tanker has been recognized as an effective countermeasure to prevent a disastrous damage induced by collisions. However, when considering that ocean-going vessels are increasing not only in size but also in speed, the threat of disastrous collision accident should be further mitigated also on the responsibility of striking ships.

2. PROJECT DESCRIPTION

The EC project is based on the assumption that sea borne transport is environmentally attractive compared to road transport per transported unit. For Europe it is particularly vital to increase short sea shipping to alleviate the increasing congestion on the main roads. However, any expansion of seaborne transport must be made with due consideration to the prevention of casualties and their consequences.

Adequate monitoring tools are important to control the performance of critical ship systems, and thereby the risk of potential breakdown. However, it is equally important to develop rational tools that give the ship crew and onshore support teams intelligent guidance if critical systems are malfunctioning.

Present ships are equipped with extensive systems for sensing and monitoring. Monitoring of propulsion systems and manoeuvring systems are standard, and hull strength monitoring systems are becoming more and more common on new vessels. However, modern sensing and monitoring systems provides a wealth of data, and the number of alarms triggered if a system fails can make it difficult to identify the actual source of the problem (“alarm inflation”). Furthermore, the systems focus on each system as stand-alone unit, and do not convey an overall picture of the risk level for the ship as a whole, making it difficult to perform an appropriate assessment of the situation. Finally, very few systems provide guidance to the shipmaster or the crew on how to operate the ship if one or more critical systems have failed.

In order to meet this challenge a joint industry project funded by the European Community under Framework Programme 6 is launched. The project is entitled: *Decision Support System for Ships in Degraded Condition* (DSS_DC). The consortium consist of: BMT, UK, The Technical University of Berlin, MARTEC S.p.a., Italy, Kongsberg Maritime, Norway, LODIC, Norway, SIEMENS Marine Solutions, Germany, the world's largest cruise vessel operator, Carnival Cruises, UK and Teekay Norway, a major owner of trading – and shuttle tankers. Marintek, Norway is managing the project.

The objectives of the project are to:

- Develop an efficient on-board Decision Support System (DSS) for handling of ships in degraded condition. Critical item: simulation / guidance modules for the main emergencies, and effective filtering of information such that the right information is displayed to the right level of decision makers on board. Alarms analysis, hierchysation, mimics and graphic interface
- Develop simulation and guidance modules for mastering a ship in heavy seas in the main emergencies:
  - Loss of propulsion
  - Damage to maneuvering systems
  - Collision / hull damage
  - Grounding
- Develop efficient systems for crisis assistance and decision support from on-shore command centres and vessel traffic control centres, based on direct information about technical condition of the ships systems. This includes systems for automated ship–shore transfer of condition data forthe on-board systems.
- Extend on-board sensing and monitoring systems with modules and models for Technical Condition Management to assess the capacity of supporting functions like e.g. power generation.
- Establish tools for consequence assessment of intentional grounding. This objective is particularly addressed in the present paper

The final outcome of this effort will be prototype installations of the developed DSS system and Man Machine Interface (MMI) on board one passenger vessel and one cargo vessel.

A crucial aspect in a critical situation is to ensure that the right information is presented to the right levels of decision makers on board and ashore. A key activity is therefore to determine the various levels of decisions makers in the process of ship operation; i.e. which decisions are made at each level in selected critical scenarios, which information is needed as basis for the decisions and how this information can be compiled and presented from the data available ("context sensitive filtering").

3. DECISION SUPPORT SYSTEM

During normal operation information is only available to the shore office or agent, but in a critical situation relevant information about the status of on-board systems should also be available to external decision makers such as the Search and Rescue team and Shore Specialist Support Services.

A system with such functionality would also allow close monitoring of vessel condition from on-shore command centers and vessel traffic control (VTC) centers. This will allow for closer integration of ship and shore based resources and effective assistance from on-shore crisis teams. As part of the present project, on-shore decision support tools will be developed to provide improved basis for routing of ships in critical areas, using the received information on hull condition, machinery status, maneuverability etc as input, in combination with available weather data.

The envisaged system relies on fast, reliable and cost-effective means of transferring data between ship and shore. Novel telecommunication systems as well as currently available systems for ship-shore data transfer will be exploited to transfer data of the condition of the vessel and on-board systems to the shore-base and port/coastal authorities. Again, a central aspect is to ensure that essential information is transmitted, and that non-essential information is filtered out to save bandwidth.

The worst outcome of a critical event is that the vessel ends up by breaking, sinking or stranding in an uncontrolled manner. The Prestige accident demonstrated that ship wrecks potentially may leak oil for years, thereby representing a continuous pollution threat. Alternatively, a last resort in a critical situation may be to run the ship aground in a controlled manner in sheltered waters, allowing e.g. for safe discharging of oil. However, running the ship aground is by itself a risky undertaking. At present, very few tools are available to the relevant decision makers to assess the consequences of such a decision.

A part of the present project is dedicated to the development of simple procedures and tools for consequence analysis of ship grounding. The tools will use information from the ship's sensing and monitoring systems as input (hull monitoring system, loading computer etc.) together with simplified numerical models for hull girder strength. Selected grounding scenarios for typical ship types will be calculated à priori to establish parametric formulae for estimated damage and contact force between ship and the sea floor. The final assessment will account for still water loading, dynamic loading from waves and tide, as well as local contact forces from the seafloor.

4. SYSTEM OVERVIEW

The system consists of a number of individual decision support modules that shall be integrated towards a common data repository and a common Man Machine Interafce (MMI). The relationship between the different functions are illustrated in Fig. 1.

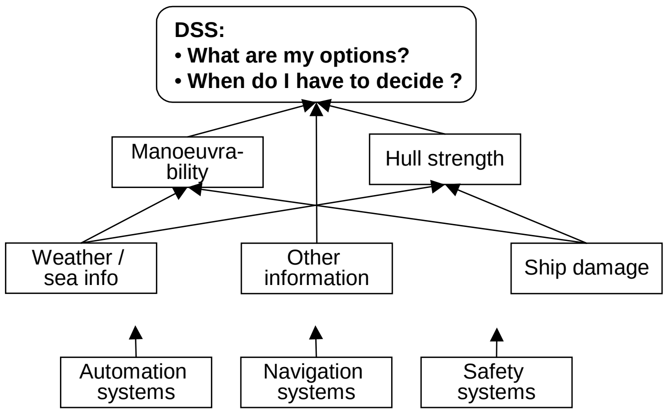

Fig. 1 System functional relationships

The system will need to address the following users, as illustrated in Fig. 2:

- The ship itself, where the DSS must be integrated with navigation and automation sub-systems
- The shore operator's emergency management team
- The Search and Rescue (SAR) authorities
- The VTS centre

- Possibly a shore specialist support centre for more advanced analyses, e.g. stability, strength and/or stranding analyses.

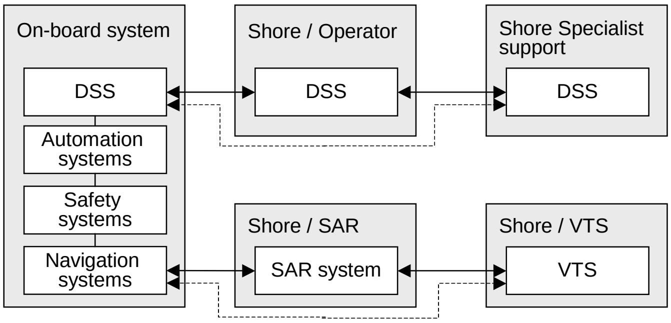

Fig. 2 System architecture

The intentional grounding simulations are envisaged as an extension to the ship's loading computer, such that tank levels, heel/trim, and damage stability information are continuously updated from the ship's systems. It is envisaged that numerical models and static (fixed) data for the vessel are maintained at a fixed data repository onboard and ashore. Tank levels and heel/trim are periodically transmitted ashore, such that specialist personnel can perform detailed analyses ashore, while quick pre-defined analyses are run continuously as background processes on board. It is also envisaged that results and assessments from shore specialist support may be transmitted on board to update the information and analysis models run by the on-board loading computer.

5. SCENARIO APPROACH

A scenario approach has been used in the development of the functional specification of the DSS system. These scenarios illustrate the practical use of the DSS, the sequence of events, the response to these events, the information required etc. for various hypotheticalevents on a tanker and a cruise ships. The scenarios identify the most important actors and the interaction between them: the crew, the shore office, the search and rescue team, and the shore specialist support center.

Eamples of scenarios are:

1. A large cruise vessel in the English Channel is rammed on port side by a smaller vessel in heavy fog. This has caused a maneuvering malfunction. The problem is to determine if the ship can be kept stable, to decide if mustering and evacuation of passengers and crew is required and how to get the ship safely to port.

The scenario is organized with three alternative outcomes, after the initial evaluation:

- Ship can sail to safe haven
- Keep vessel afloat, wait for SAR
- Abandon ship

The highlights of the scenario are:

- Assess situation, do immediate actions to consolidate situation
- If water ingress, stabilize vessel
- Assess if stability is sufficient.
- Check technical condition - can the ship reach port?
- How will current state of propulsion and manoeuvring system influence maneuverability, also including the effect of the damage?
- Monitor situation continuously. Evaluate alternative actions – keep several options open
- Situation is judged to be acceptable when passengers are evacuated. Contact SAR and arrange for safe evacuation.
- Start progress towards port.
- Flooding increases and situation escalates.
- Plan for stranding near port, if possible.
- Plan for tugs to pull ship to shallow water and strand it there.
- Evacuate.

2. A cruise ship gets a full blackout on its way out of port. The ships strands at relatively low speed on a sand bank. Tide is inward, but turns in one hour. Problems are encountered when starting up auxiliary engines.

The highlights of the scenario are:
Blackout and stranding follows. Immediate handling of situation
Assessment of situation: There is no immediate danger, but will probably stability may not be maintained at low tide. Check situation with shore

- Problem with startup of aux. engines. Water is observed in settling tanks. Initiate actions to fix.
- Assessment of situation:, is it safe to drag ship off? OK, if conducted within three hours, prior to low tide.
- Simulate different scenarios if engine power should be lost when ship is free. Narrow waters and this may be critical.
- Check technical condition to see if surprises are likely.
- Pull ship off and sail to port for check of systems and hull.

3. A tanker is on voyage in the northern North Sea, when she hits an almost submerged floating object. Hull damage and flooding of some compartments are discovered. The rudder is also damaged and jammed. Assess whether the ship can be operated properly and reach the port safely.

- Heavy weather is approaching and safe port cannot be reached without jeopardising structural integrity .
- Determine if the ship should be moved into open sea, or to a safe haven with a mapped stranding site.
- Safe haven is selected and planning commences for possible stranding, if further water ingress cannot be limited.

6. INTENTIONAL GROUNDING

Ship grounding is a very complex process. The grounding force cannot be estimated a priori. It depends on the resistance to penetration of the obstruction into the bottom of the ship, and the indentation depends again on the rigid body motion of the ship (heave, pitch, and roll) as it travels over the obstruction. Furthermore, the grounding damage will often involve deep crushing and tearing of bottom plating, stiffeners and girders over a substantial part of the ship length. Rigorous analysis of such problems calls for nonlinear finite element methods (NLFEM). However, the size of the problem makes this a tremendous task. With present computers and algorithms it will take weeks of CPU to simulate such processes, if at all successful, because the numerical solution is not a trivial task.

Considerable effort has been devoted to numerical analysis of the grounding vessels, as reported for example at the ICCGS conference in Lyngby in 2001. A review of recent research has also been carried out under the auspices of ISSC (Masour and Ertekin, 2003) and the state-of-the art paper by Wang, Spencer and Chen (2001) provides a wealth of useful information. Hull integrity during soft grounding was the subject of a study carried out by Pedersen (1994). In the Joint MIT-Industry Project on Tanker Safety (1992-2000) simplified methods were developed for prediction of the plastic energy dissipation of ship structural members in the form of fracture, tearing, folding of stiffened panels. The results of the study were used to develop the computer program DAMAGE (Simonsen and Wierzbicki, 1997). The theory of grounding on a conical rock (pinnacle) is largely based on the PhD thesis of Simonsen (1997). A very important aspect is verification of the tools developed this being simplified methods or advanced nonlinear finite element analysis. Benchmark tests as those initiated by ISSC (Masour and Ertekin,

2003) are very valuable for this purpose.

An operational decision support system requires the grounding simulation to be performed within seconds. This will be achieved by:

- Decoupling the rigid body motion and the resistance to penetration of the bottom structure.
- Predetermined resistance - penetration relationships for the typical ship bottom structures

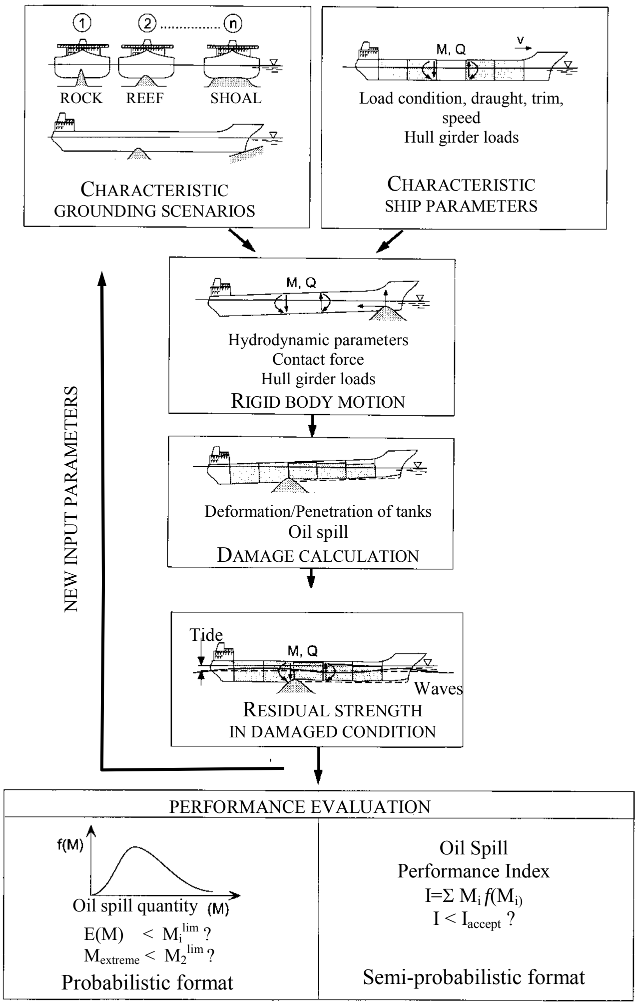

Fig.3 Ouline of a design procedure

The procdeure that is adopted follows to a large extent the approach oulined by Amdahl , Kavlie and Johansen (1995) and is sketched in in Fig. 3.

6.1 *Rigid body motion and loadst*

The rigid body motion is represented by six degrees of freedom. It is convenient to distinguish between motions in the vertical plane; heave, pitch, roll and the horizontal plane; surge, sway, yaw. The coupling between them is weak and can be disregarded for grounding analysis. The vertical motion may be determined from hydrostatic considerations using a ship load and stability calculator, including the grounding contact force. In the present project the SHIPLOAD will be used, but information form alternative calculators, e.g. NAPA should be considered.

The necessary input to this analysis comprises:

- ship hydrodynamic data
- ship light-weight distribution
- load condition, including bunker situation and potentially flooded compartments
- initial draught and trim (which may be calculated from the above information)
- hull girder load effects (stresses) from monitoring system (if known) – this may alternatively be estimated from the above information

Intentional grounding is as slow process, so that transient dynamic forces may be neglected.
The effect of grounding is represented as a concentrated force corresponding to the instantaneous indentation of the sea floor into the ship bottom for a single point contact or a series of patch loads if grounding takes place over a large area,. At a given time the estimated grounding force is input to the load calculator. The updated mean draught, trim and roll angle in the next time increment provide the necessary information to calculate the next level of indentation of the sea floor into the bottom, and hence, the new grounding force. This is illustrated in Fig. 4.

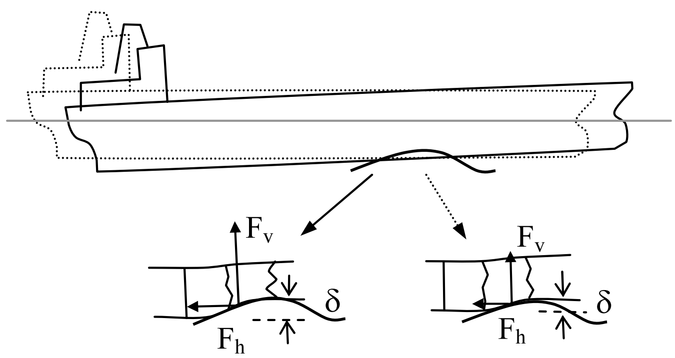

Fig. 4 Model of the grounding process

The load and stability calculator will also assess the hull girder load effects – i.e. global bending moment and shear force, including the effect of the grounding force. These will be evaluated against the available hull girder resistance in shear and bending. Any degradation of the resistance due to bottom damage is accounted for.

The rules of the ship classification societies contain requirements to the hull girder resistance in intact and damaged condition. The requirements may be used directly, but the ultimate resistance is normally somewhat higher. Ultimate hull girder resistance is still a subject of considerable research, noticeably under the auspices of ISSC (Ohtsubo and Sumi, 2000). The detrimental effect of damage has been studied by Wang, Chen, Zhang and Peng (2002).

Roughly speaking, waves contribute by 2/3 to the total hull girder design loads. During intentional stranding the wave loads are normally small compared to the design wave loads, so that grounding and still water loads considerably beyond still water design loads may be allowed.

As illustrated in Fig. 5 the ultimate resistance of the hull girder in bending should be presented on a monitor to the ship crew along with current “utilisation” in the form of still water loads and wave loads. The estimated reduction in capacity due to damaged bottom panels should be visualised as a drop in the capacity curve. Preferably, the predicted increase of wave loads due to forecasted aggravating weather and any degradation of the capacity due to progressive development of damage should be indicated. Of course, the still water load may also change due to change in contact force, flooding or outflow from tanks etc.

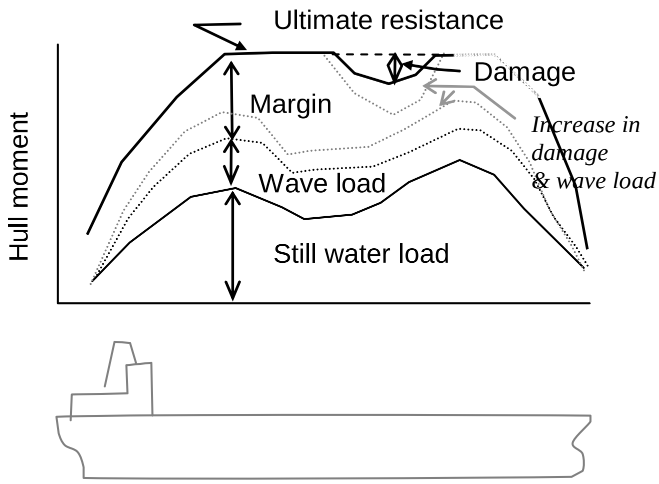

Fig. 5 Hull girder bending moment distributions

6.2 *Grounding force*

The resistance to penetration of the bottom structure will be calculated by phenomenological numerical formulations which have been validated against test data and results from NLFEA. As the bottom structure is fairly constant over the cargo area, it is only necessary to model a part of the ship, say a tank length for NLFEA. The resistance to penetration is analyzed for a constant indentation by first pushing the obstruction the selected distance into the bottom, followed by motion along the ship. This provides information of the vertical and horizontal component of the contact force in the “steady-state” phase. Analyses are performed for a large number of indentation levels. Having established the resistance for various indentation levels, the actual resistance based on the indentation calculated in the rigid body motion analysis can be determined by means of interpolation. A separate analysis has to be performed for the foreship body, i.e. ahead of the collision bulkhead.

The harmonization of ship classification rules ensures that ships are fairly consistently built. Within each size category of a ship type, different structural arrangements may therefore be classified into a small number of characteristic groups. For each group and sea floor characteristics the resistance to penetration will be established as described above.

As mentioned above it is essential that theoretical analysis be verified against experiments. Fig. 6 shows experiment carried out by Amdahl, Kavlie and Johansen (1995) with a double bottom model subjected to a lateral indentation by a conically shaped obstruction. Comparison with numerical simulations shows that the collapse mode is traced with good accuracy. The major reason for discrepancy is related a premature rupture due to weld discontinuities and/or geometric inaccuracies.

In addition to calculating the grounding damage, the potential degradation of the hull in stranded condition will be analysed, taking into account the effect of tides and waves and possible outflow of cargo and/or flooding of tanks. This may also be used to assess the force required to pull the ship of the off the ground.

The outcome of the grounding simulations is information of:

- Likely damage of the ship bottom due to grounding
- rupture of cargo tanks
- amount of cargo spill
- hull girders stresses to be evaluated against ultimate hull girder resistance

Fig. 6 Double bottom subjected to lateral indentation

The outcome of the stranded analysis is information of:

- prediction of potential damage escalation if the ship remains in stranded condition, taking into account weather forecasts. This includes hull girder loads and strength assessment
- required tug forces to pull the ship off the ground

In order to illustrate the approach results from simulation of the grounding by a 280,000 dwt tanker are presented (Amdahl, Kavlie and Johansen, 1995). Assuming the reef to be a truncated cone two cases were analysed as; one with a fairly narrow and sharp cone, the other with a blunt cone, refer Fig. 7. The force-indentation relationship for the tanker simulated with the LS_DYNA code is shown in Fig. 8. Such curves were used to establish simplified force-indentation curves to be used in simulation of the rigid body hull girder motion.

Assuming the speed at the instant of grounding to be 4 m/s and the obstruction to rise 4 m above the mean draught of the ship, the rigid body motion simulations predicted very different damage for the two obstruction cases. In case of the narrow cone a major part of the hull girder is damaged, refer Fig. 9, while the damage is limited the first tank in case of the blunt obstruction.

The grounding speed assumed in this study is obviously much larger than the likely speed in intentional grounding, where the damage will – and has to be - much smaller. However, the principles of calculation are the same

6.3 *Fracture*

A crucial issue in conjunction with the bottom damage simulation is to predict the onset of fracture in the cargo tanks – in the outer skin for single hull tankers and the inner bottom for double hull tankers. This requires careful modelling of critical details and relating this to fracture initiation models. Many methods have been proposed in order to describe fracture initiation and propagation. The simplest and commonly most used fracture parameter in commercial finite

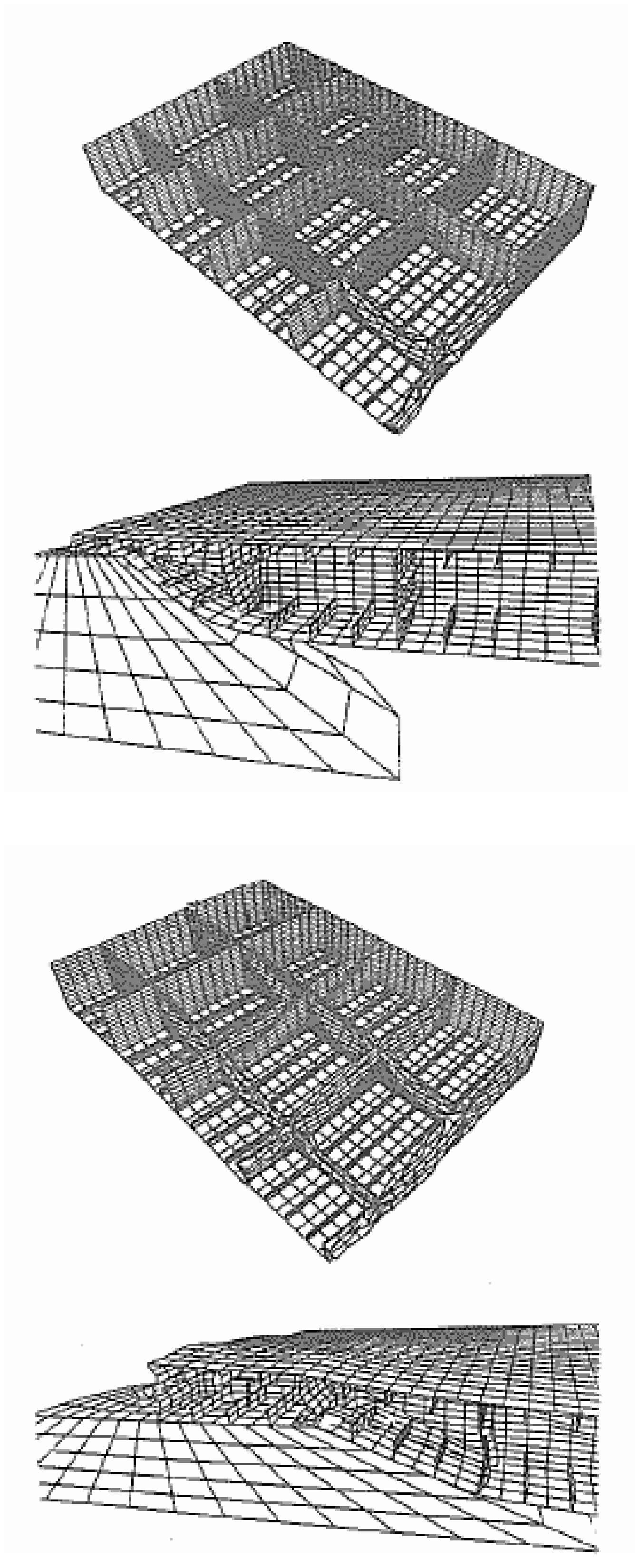

Fig. 7 Finite element model of narrow and blunt sea floor obstruction.

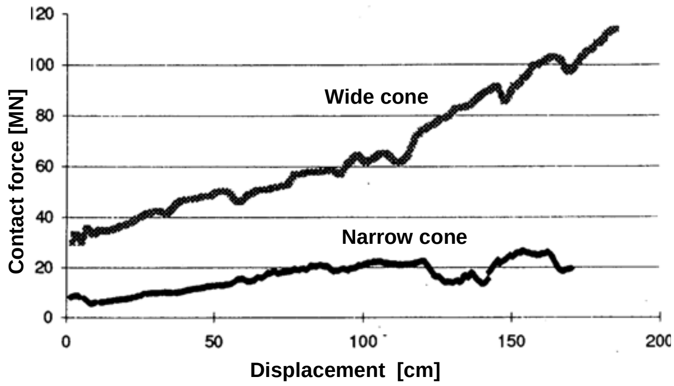

Fig.8 Force-indentation relationship for narrow and blunt sea floor

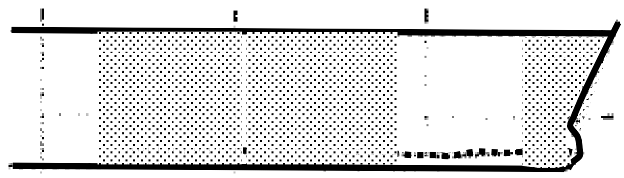

Fig.9 Simulation of damage to cargo tanks.

element (FE) software is the equivalent plastic strain ε_{cr}. As the elements in a FE model exceed the critical straining value, the element is either removed or element ties are released in order to simulate fracture.

An obvious problem employing the effective strain is that it is a constant parameter, which will lead to fracture in pure compression as easily as in tension. Since the effective strain will vary with different types of loading such as pure tension, shear, and combinations of these, it is somewhat unsuitable for simulations with large variation in stress states. More suitable fracture methods, such as the well known void growth models studied by McClintock (1968) and Rice and Tracey (1969) introduce triaxial states of stress σ_m/σ_{eq}. Where σ_m is the mean stress and σ_{eq} is the equivalent stress. Unfortunately, these models cover only the tensile dominated stress triaxiality regimes. Combinations of different fracture methods are therefore necessary in order to cover the entire triaxial stress range. An example of this is the fracture model studied by Bao and Wierzbicki (2004) which uses a Crockcroft Latham formulation for the lower triaxiality range, $-1/3<\sigma_m/\sigma_{eq}<0$, and the McClintoc model for the higher regime, $\sigma_m/\sigma_{eq} > 1/3$. The shear dominated zone $0<\sigma_m/\sigma_{eq}<1/3$ is determined by experiments and numerical simulation.

In general, when implemented into finite element codes, fracture models give good prediction of the crack propagating behaviour and global deformation response. However, this is on the condition that the fracture method is adapted to the model mesh size and shape. A general problem here is that FE models are very mesh size dependent. That is, various mesh sizes modelling the same problem, give different predictions of stress and strain. Fracture models based solely on element strain or damage values may therefore lead to different tolerances to fracture, and thereby different structural behaviour.

Various means to control the mesh size effect have been studied. It has been shown by Lee, Wierzbicki and Bao (2003) that by averaging the fracture parameters over a defined volume, the mesh size effect is eliminated. However, practical use of this method requires that the critical fracture values over the averaging volume be known. More recently, Simonsen and Törnqvist (2004) have proposed the idea of determining the fracture parameter by using predefined damage value vs. element size relations. The method has proved to give good results in problems dealing with relatively large mesh sizes, such as for ship grounding simulations.

6.4 *Bottom topology*

A factor of paramount importance is the sea floor conditions at the stranding site. In general the conditions may vary from soft bottom (clay, sand) to sharp, rigid obstructions like sharp pinnacles. Obviously, it will be extremely beneficial if a survey of the sea floor characteristics at potential grounding locations is performed and assessed with respect to functionality. Preparation of the sea floor in order to smooth the surface and remove unfavourable obstacles may also be envisaged. The actual conditions should constitute the basis for the modelling of the sea floor in the bottom damage simulations.

Potential locations which are particularly favourable with respect to intentional stranding have been identified by the Coastal Directorate in Norway, see Fig. 10. No detailed survey of the sea floor has, however, been undertaken.

Fig. 10 Potential stranding sites along the coast of Norway.

The environmental conditions at the grounding site should also be mapped so that their effect on the hull girder can be evaluated. Tidal variations are obviously very important, because large changes in trim and/or draught of a stranded vessel may result in excessive hull girder forces. Even if the grounding preferably should take place in sheltered waters, wind and waves actions may induce significant forces on the hull girder. Shallow water effects may also have to be considered.

The motions in the horizontal should normally consist of mainly longitudinal retardation of the ship until it comes to a complete stop. If the grounding point is very much off centre, some gearing may occur. Wind and wave action could cause the stranded ship to sway and/or gear if it is not sufficiently moored.

Scenarios even worse than those outlined above, may be envisaged: If the emergency response system is not sufficient, a tanker may, unavoidably, drift ashore at a very unfavourable location (uneven sea floor, high environmental exposure etc.) or location with very limited information, the system should preferably be able to handle this case as well

CONCLUSIONS

The basic ideas behind a calculation model for assessment of bottom damage and hull girder loads to a vessel during grounding have been outlined. The ambition of the work is to predict the consequences with such a precision that decision whether a disabled ship may be safely stranded (integrity maintained, no or minimal oil spill) can be made with a high degree of confidence. In addition to being reliable the calculations must be carried out within seconds in order to allow for fast evaluation of alternative actions to maintain integrity of the vessel. The work is part of project devoted to development of a decision support system for ships in disabled condition in general.

ACKNOWLEDGEMENTS

The information embedded in the present paper is generated as part of the EC project *Decision Support System for Ships in Degraded Condition* (DSS_DC) carried our by a consortium consisting of MARINTEK (NO), BMT (UK), The Technical University of Berlin (D), The Norwegian University of Science and Technology (NO), Carnival Cruises (UK), TeeKay Norway (NO), MARTEC S.p.a. (I), Kongsberg Maritime (NO), LODIC (NO) and SIEMENS Marine Solutions (D). The financial support of the European Commission is gratefully acknowledged, as is the technical and operational contributions from Carnival and TeeKay to the use case scenario. The authors also wishes to thank dr. Ørnulf Rødseth for invaluable contributions to the work.

Please note that whilst every effort has been made to reflect the intentions of the project development within the present activity, neither the project team nor the participating companies or organisations will assume any responsibility for use of the present information. Also note that participation in the DSS_DC project does not imply full endorsement of every element in the project deliverables.

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