METHODS FOR EVALUATING THE SAFETY OF SHIPS ON DIFFERENT ROUTES

by

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ABSTRACT

Two Coast Guard R & D projects are discussed which are related to the safety of merchant ships and fishing vessels. Both projects are concerned with large amplitude, wind and wave induced, ship motions. They are directed toward the prevention of the loss of life and property due to capsizing and the shipping of water. One project called Advanced Computational Techniques is targeted at merchant ships. It seeks to establish a rational mechanical basis for the assignment of load lines and the establishment of structural strength and stability criteria. The other project is called Fishing Vessel Stability. It will attempt to establish a basis for candidate stability standards for fishing vessels.

DISCLAIMER

The views expressed herein are the opinions of the author and not necessarily those of the Department of Transportation or the U.S. Coast Guard.

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INTRODUCTION

Tonight, at this session dealing with the motion of ships in waves, I would like to discuss a couple of Coast Guard R & D projects which are related to the safety of merchant ships and fishing vessels at sea. This will give you some indication of where our interests lie.

One of the many missions of the USCG is the protection of life and property at sea by the establishment and enforcement of marine safety standards. The ideal standard seeks to insure safety without unduly influencing the ship design or unnecessarily affecting the economy of operation. This ideal can be approached by improving the ability of regulators to predict the impact of innovative design features and operation on safety.

One major safety concern is the prevention of the loss of life and property due to capsizing or the shipping of water. This concern applies to both merchant ships and fishing vessels. Merchant ships are presently regulated by the Coast Guard. Fishing vessels are not. The first project which I will discuss is called Advanced Computational Techniques. It is primarily targeted at merchant ships, with an anticipated spin-off application to fishing vessels. The second project is called Fishing Vessel Stability. It is targeted at fishing vessels. Both of these projects are concerned, in part, with large amplitude, wind and wave induced, ship motions.

BACKGROUND FOR ADVANCED COMPUTATIONAL TECHNIQUES

Current regulations seek to prevent capsizing or the shipping of water by setting minimum stability and freeboard requirements for merchant ships. These regulations are based on hydrostatics. They were developed from an analysis of, and experience with, traditional ship configurations.

For example, Code of Federal Regulations section 170.170 requires merchant ships (with certain exceptions) to have a metacentric height sufficient to resist prescribed wind heel moments.

Load lines, the well known Plimsoll marks on the side of a ship, are assigned by the American Bureau of Shipping in the United States. The Coast Guard maintains an oversight role over this function. The Plimsoll marks afford a quick visual check that a vessel is not overloaded. Load line assignment is concerned with such factors as reserve buoyancy, structural strength and the height of working platforms above the sea. The loadline determines the minimum freeboard required for a given design, and a given service.

Load line assignment is the subject of the International Load Line Convention as well as federal law. The oceans are divided into various zones and seasonal areas under the regulations. These zones and seasonal areas reflect the probable severity of the weather encountered by the ships engaged in commerce. The basic load line is drawn through the load line disc on the side of a ship, and determines the basic Summer Zone freeboard in salt water. The freeboard may be reduced for the Tropical Zone, but must be increased for the Seasonal Winter Zone, and increased still further for the Seasonal Winter North Atlantic Zone. Provision is made for adjustments in the marks for fresh water.

The regulations require that a vessel be loaded for departure on a voyage, in such a way, that the applicable seasonal mark is never submerged (in calm water) during any portion of the voyage. Safe loading, therefore, depends on the route followed, and this in turn depends on the probable severity of the weather expected to be encountered during the voyage.

A number of concerns can be raised about the existing regulations. First, as new ship forms are developed, the rules based upon experience may not be applicable. This can result in either excessively restricting or inadequate rules. Another consideration is the ability of the simple methods to deal with extreme or unusual environmental conditions. The available tools are hydrostatics, and linear, "strip theory," seakeeping computer programs. These tools are adequate while a ship is undergoing small-amplitude motion and a moderate sea. Even then, it would be desirable to establish regulations based upon a statistical analysis of the vessel's response to expected seaways. Unfortunately, safety concerns almost always arise while a ship is undergoing large amplitude motion or is operating in a severe sea. The lack of proper tools for analyzing the dynamic stability of a ship and determining freeboard based upon the nonlinear interaction between the ship and the ocean environment may result in inappropriate regulation of ship operation.

A third consideration is the limited ability of simple methods to predict the structural loading on a hull subjected to extreme or unusual environmental conditions. The available tools are a statically balanced "hogging" and "sagging" analysis based upon a "standard" L/20 trochoidal wave using hydrostatics, or the statistical loading predicted by linear, "strip-theory" seakeeping computer programs. These tools are adequate while a ship is operating in moderate seas. There are indications, however, that structural integrity may be placed in jeopardy when large high-speed ships operate in severe seas. Better tools are needed for the analysis of loads arising from the nonlinear interaction between the ship and the ocean environment.

APPROACH FOR ADVANCED COMPUTATIONAL TECHNIQUES

An advanced computational method is being developed to predict both the motion and stability of a ship in waves, and the hydrodynamic loads on a ship in waves. The following aspects of the research project are being, or will be, addressed:

1. Analyze existing world-wide wave data to develop appropriate seasonal wind and wave criteria for ship design and operation in different areas of the world.
2. Develop statistically based extreme value environmental parameters for stability and seakeeping criteria.

3. Develop three-dimensional time-domain computational techniques for analyzing dynamic stability, hydrodynamic loading, and the seakeeping of vessels in waves.
4. Develop nonlinear computational methods for the analysis of phenomena such as deck submergence, the effect of free water on deck, and very large amplitude motions.
5. Evaluate the sensitivity of coefficients in the equations of motion to minimize the complexities of computer calculations to better understand the importance of various parameters in dynamic stability and seakeeping.
6. Determine appropriate methodologies for expressing stability, seakeeping, and strength in terms of environmental parameters and vessel hull loading parameters..
7. Verify the utility of the methodologies developed by analyzing vessel casualties.

The first two aspects of this project are being addressed by Mr. William Buckley of the David Taylor Research Center under a project to develop extreme and climatic wave spectra for use in analyzing the world wide operation of ships. Mr. Buckley has analyzed long term NOAA buoy wave spectrum data. He has computed global wave statistics from British Maritime Technology (BMT-GWS data) with NOAA wave data. He will then synthesize NOAA buoy data and BMT-GWS to produce reliable global wave climate information.

Mr. Buckley has worked to establish an envelope of extreme values of significant wave height versus modal period. He is attempting, at present, to provide closed form three parameter Ochi, or possible JONSWAP, wave spectrum approximations for this envelope. He is defining climatic, or intermediate, and extreme wave spectra. This will provide wave spectrum data for computer and towing tank modelling of seaways. These spectra will also provide forcing functions for nonlinear ship motion studies sponsored by the Coast Guard in the future. Mr. Buckley will consider the application of design wave climate data to the rational development of load line criteria. This will include consideration of geographic and seasonal wave climates. He will consider the application of design wave climate data to the development of intact stability criteria.

The next two aspects of this project are being addressed by Dr. Nils Salvesen of Scientific Applications International Corporation under joint DARPA, Coast Guard, NAVSEA, ONR funding of an ONR contract to develop in Interactive Design, Evaluation and Analysis System (IDEAS). IDEAS is bringing a geometry code, first level hydrodynamic codes for powering and linear seakeeping, and design criteria evaluation codes together on a state of the art engineering/graphics workstation. In addition, the designer will have direct access to advanced hydrodynamic codes for nonlinear seakeeping on a super computer. This will bring an unprecedented capability to the ship designer's desk top. The Coast Guard's R & D interest is centered on the advanced hydrodynamic codes for nonlinear seakeeping.

The nonlinear seakeeping codes contain six degree of freedom, large amplitude, time domain, rigid body dynamics, automatic repanelization of the underwater portion of the hull, and the calculation of hydrodynamic forces and moments on the hull by integrating the pressure over the underwater portion of the hull at each step in time. The pressures are calculated using algorithms which satisfy exact boundary conditions on the water. The approach is three dimensional. The computational method is structured to allow nonlinear free-surface boundary conditions to be incorporated into the codes as advances in this area are made.

A comparison of the ship's bending moments predicted using three dimensional hydrodynamics and nonlinear motions codes with those predicted using strip theory and linear motions codes for a series 60 merchant ship will be made this year. A similar comparison of green water on deck predictions will also be made. A study of the capsizing of a series 60 merchant ship, or a fishing boat, in beam seas will be made next year. A study of the motion of a fishing boat in extreme quartering seas will be made during the following year. The last three aspects of the Advanced

Computational Techniques project will be addressed in time, as confidence builds in the advanced hydrodynamic codes contained in IDEAS.

BACKGROUND FOR FISHING BOAT STABILITY

Commercial fishing is the most dangerous occupation in the United States. Severe weather, cold water, long hours, and physically demanding work all contribute to the hazards inherent in making a living from the sea. Statistics indicated that the primary cause of capsizing and sinking of fishing vessels is insufficient stability. This is a result of, or a combination of, poor design, improper loading, and progressive flooding in a seaway. Often vessels are designed with marginal stability to start with, and are subsequently modified by their owners without regard to effects upon stability. It is not surprising that an average of 250 vessels and 84 lives are lost each year.

With the enactment of Public Law 100-424, "Commercial Fishing Industry Vessel Safety Act of 1988," the Coast Guard will require that fishing vessels built, or substantially altered, after 31 December 1989 have adequate acceptable operating stability. The Coast Guard will most likely require that a classification society such as the American Bureau of Shipping review and certify that each fishing vessel complies with this requirement.

Naval architects tend to think that ship stability is characterized by calm water static stability. Some criteria, like Code of Federal Regulations section 170.170 analyze the initial slope of the righting arm curve and range of stability. Other criteria analyze the total character of the righting arm curve.

It is envisioned that the voluntary stability standards presented in Navigation and Vessel Inspection Circular 5-85, "Proposed Voluntary Stability Standards for Uninspected Commercial Fishing Vessels," will be used as a basis for certification. These standards consist of the International Maritime Organization Resolution A.168(ES.IV), commonly known as the Torremolinos Convention Criteria, and the IMO Severe Wind and Rolling Criteria for intact stability. These standards analyze the total character of the righting arm curve, but still treat an essentially dynamic problem as a problem in statics.

Navigation and Vessel Inspection Circular 5-85 contains a caution about using these standards for fishing vessels less than 79 feet in length. These standards were developed from an analysis of world fishing fleets, but only considered vessels over 79 feet in length. In addition, operations which affect vessel stability will be considered in the evaluation of existing standards, and the development of any new candidate standards. Navigation and Vessel Inspection Circular 5-85 gives specific guidance which takes care of the reduction of stability resulting from towed nets, ice accretion, water on deck, etc. Such operations may have a more significant effect on the stability of fishing vessels under 79 feet in length than they have on the stability of vessels over 79 feet in length. This project will, therefore, include a study of how such operations affect stability characteristics.

APPROACH FOR FISHING VESSEL STABILITY

It is necessary to gather an extensive amount of background material in order to determine an appropriate stability standard for U.S. fishing vessels. Therefore, the following preliminary tasks must be accomplished. The work is being done by Wartsila Marine Inc. of Vancouver, B.C. in Canada:

1. Fishing vessel casualties will be reviewed and categorized on a world-wide basis.
2. Detailed information will be gathered about the laws or requirements affecting fishing vessel stability from all nations with major fishing fleets.
3. A survey of the U.S. fishing fleet will be performed by geographic location and vessel type.
4. A world-wide review of the current state of stability research will be conducted.

The fishing vessel casualty survey will include collision, fires and explosions, groundings, capsizing, founderings and equipment failures. The vessel length, design type, gross tonnage, national registry, injuries and loss of life will be recorded for each casualty. Casualty rates will be estimated on the basis of the total number of vessels in each fishery.

Detailed information about the laws or requirements affecting fishing vessel stability will be obtained from at least Canada, the United Kingdom, Japan, Norway and the Union of Soviet Socialist Republic. Detailed requirements in the form of equations, minimum areas under the righting arm curves, etc., will be presented in tabular and graphical format. The loading conditions for which these regulations apply will also be noted.

A handbook of U.S. fishing vessels will be prepared in a report format. All typical fishing vessels within each geographical area will be presented. The geographic areas will include Alaska, Pacific Northwest, Gulf of Mexico, New England offshore and coastal, and southwest. If available, a photograph or drawing, lines plan, table of offsets, and typical characteristics such as displacement, length overall, beam, and draft will be presented for each vessel. A static stability curve or righting arm versus heel angle will be included for a loading condition corresponding to a full catch and half full fuel oil and water tanks. A comparison of each example with the Torremolinos criteria shall be assumed.

The review of stability research is intended to identify research needed to develop appropriate stability standards for U.S. commercial fishing vessels. This task will begin with a comprehensive review of stability research for vessels in general, and then focus in on the research applicaboe to fishing vessel stability. Static and dynamic stability will be covered. The effects of water on deck, flooding, icing, tripping by towed nets and any other hazards specifically associated with fishing vessel operation will be covered. A discussion of past and present research into nonlinear rolling will be included.

We will identify additional research which needs to be conducted based upon the results obtained from the preliminary tasks discussed above. It is envisioned that the additional research will include some combination of model tests and numerical analysis. The model tests would probably be conducted using self-propelled, radio controlled models with on-board data acquisition systems. Concurrent with the model testing, a study will be conducted to evaluate how well numerical simulation can predict vessel capsizing.

CONCLUDING REMARKS

I have briefly discussed two Coast Guard R & D projects which are related to the safety of merchant ships and fishing vessels. Both projects are directed toward the prevention of the loss of life and property due to capsizing and the shipping of water. Large amplitude, wind and wave induced, ship motions must be addressed in both projects. The Advanced Computational Techniques project will be used to arrive at a more rational basis for the assignment of load lines, and the determination of structural strength and stability requirements. The Fishing Vessel Stability project is directed toward the establishment of candidate stability standards for commercial fishing vessels. The goal is the establishment of standards which insure safety without unduly influencing ship design or unnecessarily affecting the economy of operation. Our most difficult task will be translating the results of the sort of mathematical analysis which is the subject of this workshop into simple, unambiguous rules, regulations and standards.