Ship Stability - Working with the Operator

Andrew J. Peters, *QinetiQ Haslar Marine Technology Park (UK)*

Stephen Marshall, *MoD, DPA, Sea Systems Group, Surface Ship Hydromechanics (UK)*

ABSTRACT

A strategy has been developed in the UKMoD which brings the operator and scientist closer together to further advance ship safety. It has been known for some time that the ability and experience of the ship operator has a large influence on the overall level of safety of the vessel. This paper discusses the recent interaction between the scientist and the operator which has provided a greater insight into how ships are operated in heavy weather, and has allowed the operator to gain from the latest knowledge and tools developed by the scientists.

Traditionally, guidance in how to operate ships and ship systems in extreme weather forms part of the seamanship lectures given during navigational training and through experience at sea. Additional onboard assistance is provided for ship/aircraft operations in the form of Ship Helicopter Operating Limits (SHOLs) but these have no predictive capability.

Currently, computer based tools providing guidance on how to minimise the risk to the ship and ship systems in severe seas are not in routine use by the Royal Navy. There is a very small amount of ship specific guidance provided but this tends to consist of ship manuals which have very limited use *in situ*.

1. INTRODUCTION

In 1990 the Cooperative Research Navies (CRNAV) Dynamic Stability group was established with the aim of deriving dynamic stability criteria for naval vessels. To derive such criteria, the group needed to evaluate in-service and new ship designs, in moderate to extreme seas in terms of their relative safety and probability of capsize. This would ensure that new vessels continued to be safe, while avoiding high build and life-cycle costs associated with over-engineering.

To achieve these objectives the numerical simulation program FREDYN was developed, and continues to be applied extensively – both to intact and damaged ships. This time-domain program is able to take account of nonlinearities associated with drag forces, wave excitation forces, large-angle rigid-body dynamics and motion control devices. The current CRNAV group comprises representatives from UK MoD, Naval Sea Systems Command (NAVSEA), the Australian, Canadian, French and the Netherlands navies, as well as the U.S. Coast Guard, Defence Research & Development Canada, (DRDC), Maritime Research Institute in the Netherlands (MARIN), Naval Surface Warfare Center Carderock Division (NSWCCD) and QinetiQ.

The objective of this paper is to discuss the work that is currently being conducted for developing and implementing shore based training and active on-board operator guidance to deliver improved operational capability, increased availability, lower through life costs in normal conditions and

reduction of risks of loss in heavy weather.

2. MAINTAINING CAPABILITY

The maintenance of a maritime strategic capability demands the capability of rapid deployment to any area of conflict or humanitarian crisis. The naval operational philosophy and doctrine places major demands upon vessel and crew with respect to high risk/threat encounters, be they military or environmental. The seakeeping performance of naval shipping is a key enabler in delivering this capability. Operational requirements demand that mission effectiveness is maintained even in rough weather and the ships are able to survive extreme weather conditions. Examples of such capability and safety requirements are:

- Ship Speed
- Weapon & Sensor effectiveness
- Ability to launch & recover and handle aircraft
- Replenishment at sea
- Crew effectiveness and safety
- Structural integrity
- Intact survivability

The operational capability of a warship will be reduced due to excessive motions and related phenomena in bad weather. The seakeeping and dynamic stability characteristics of a ship are fixed early in the design process and, once in service performance is reliant upon the precepts of good seamanship in course and speed selection. Traditionally, guidance on how to operate ships in rough & extreme weather to maximise capability forms part of generalised seamanship classroom lectures given during navigational training and through feedback from experience. There is a very small amount of ship specific guidance provided but this tends to consists of only paper copies of a few graphs which have very limited use *in situ*.

With the growing complexity of equipment and the general reductions in manning levels mean a greater workload on operators to deliver capability. Furthermore, with the current trend towards having less time at sea, the experience of extreme conditions will perhaps become more infrequent. Seamanship training is classroom based as is the teaching of heavy weather doctrine as the UK simulator facilities at HMS Collingwood in Gosport, were not designed for this capability. It is believed that the training requirements to reverse the trend in the decline in heavy weather experience can be addressed through a combined approach of validating doctrine for modern naval hullforms, conducting heavy sea simulator training and implementing onboard operator guidance.

3. SIMULATOR AND COMPUTER BASED SEAMANSHIP TRAINING

Although heavy sea doctrine exists in order to safeguard operations in hazardous situations there is great benefit, prior to exposure to the real conditions, in being able to train for such eventualities in a safe environment. In general, time at sea has reduced over the last 50 years and thus experience is, in general, less amongst today's navigators & seamen. However well skilled operators are, heavy weather damage does occur leading to downtime and a loss of availability.

The CRNAV group has linked the FREDYN program to the simulator at the Royal Netherlands Navy KIM facility at Den Helder in order to assess the feasibility to assess extreme sea ship handling training in a simulator environment. CRNAV have held two workshops at the facility so far. These workshops demonstrated the feasibility of using simulators to assess current doctrine in a safe training environment. Further work however is required to improve operator cues such as deck wetness, slamming and the sea

surface definition. At the most recent workshop the active operator guidance system ORPHEUS (described later) was integrated with the simulator to test and demonstrate the benefit of such a capability.

Prior to assessing the feasibility of transferring the technology demonstrated at Den Helder to the simulator at HMS Collingwood, QinetiQ and the UKMoD have developed a user friendly version of the FREDYN programme to allow operators to quickly and easily evaluate doctrine and associated manoeuvres and operations in rough and extreme weather in different ship conditions. This capability, known as Easy-FREDYN, is a cheaper and easier solution, installed in the computer based training facility (CBT) and provides an effective way of introducing heavy weather training into the already packed RN training programme.

Figure 4-1 Easy FREDYN

Easy-FREDYN also has the facility for demonstrating hazardous situations through a number of “pre captured runs” to illustrate the conditions where broaching, and capsize through a loss of dynamic and static stability can occur.

Having Easy-FREDYN in the CBT facility allows the officers to get a good understanding of their vessels behaviour in heavy weather before they actually join the ship, or the ship actually enters service.

4. ACTIVE OPERATOR GUIDANCE

Advances in the accuracy of computer based modelling and simulation tools, have given rise to the opportunity to use ship specific simulations as a base for supplying information as part of an onboard decision aid tool. Such a tool would increase the operational envelope and/or improve operational safety of most shipboard tasks that are degraded by the presence of rough weather.

The UKMoD and QinetiQ have developed an understanding of how information can be provided to the operators in a clear, concise but useful manner to improve capability in rough weather and risks of damage or in the extreme loss, in extreme seas. This work resulted in a prototype demonstration system named, ORPHEUS, (Onboard Risk Performance Hazard EvalUation System) which was evaluated in 2004 on a Type 23 frigate during exercises in rough weather off the West Coast of Scotland.

ORPHEUS can provide information on course and speed selection to minimise motions for tasks often limited by ship motion, such as safe aircraft operations, helicopter removal of injured crew, towed array/towed body deployment, small boat operations and weapon firing. In non-combat scenarios the system will aid operators to maximise crew comfort and crew effectiveness. There is also the benefit of maintaining the safety of cargo stowage.

In respect of aircraft operations, the use of ORPHEUS would maximise the launch and recovery envelope of embarked aviation assets including UAVs, in all sea states and ensure the safety of both aircraft and personnel while operating on deck in adverse conditions.

ORPHEUS provides a means of displaying measured motions, predictions of motions at alternative speeds and heading

combination alongside operating limits, thus providing a decision aid tool to the officers on the bridge. The MS Windows® based system combines real-time information with a database of previously generated results which are then plotted to the screen when selected. This flexible approach allows future developments to be easily incorporated, where the pertinent ship motions can be combined to provide an overall operability plot relating to the specific ship task.

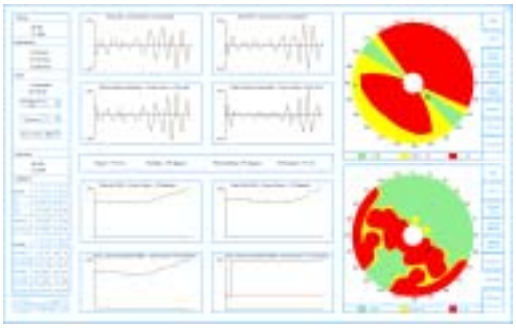

Figure 5-1 ORPHEUS day View

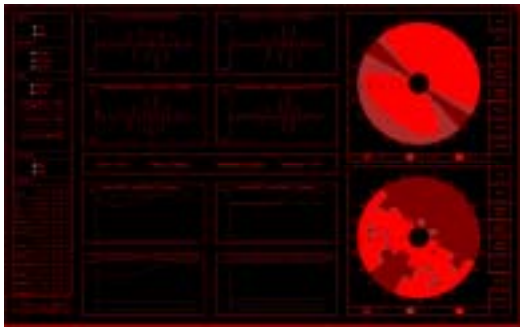

Figure 5-2 – ORPHEUS Low Light View

Simple to interpret polar contour plots provide a method of deciding how ship speed and course changes might affect their ability to perform their tasks interpreting the data for several speeds and headings. The important point being to provide useful and understandable information to the officers on the bridge in the form of guidance plots, for example, of helicopter operations, crew comfort & effectiveness, boat operations, slamming, deck wetness as well as hazardous situations such as broaching and capsize.

Royal Navy feedback on the 2004 sea trial was very positive and hence the UKMoD decided to enhance the capabilities of the system. QinetiQ have undertaken a development program to enhance the tool into a full Naval solution.

5. ORPHEUS DEVELOPMENT

The increasing complexity of ship and aircraft systems means a decision support aid that provides information giving guidance on the ability to undertake aircraft operations is of value. This information must, of course be in a form that the operator can use in a meaningful way.

A system of monitoring the current level of motions is a key part of an operator guidance system. The operators needs to be presented with reliable information on the condition of the ship and the effect the waves are having on it before they can take a decision to alter speed and or heading. Whilst the advisory part of the systems predicts the ship motions given the seaway, the motion monitoring is done using a small standalone instrumentation system developed by QinetQ to measure and display the actual ship motions.

The ORPHEUS system provides statistical and risk based information detailing options for speed and heading changes that reduce the impact of the wind and wave environment on their ability to undertake operations. One issue that has been apparent when designing the operator guidance tool is the need to ensure that information is presented in a meaningful way and that the human machine interface (HMI) is considered from an ergonomic point of view.

The presentation of the live motion feedback, the polar plots and the long term statistical data, have been investigated in close collaboration with the operators both within the UK and the other Navies. The future enhancements will look at building on

the current usability of the system both in day and night operating modes.

The range of data that can be incorporated into the system is still evolving. A number of new operational plots are currently been reviewed and discussed with the operators such as further plots for air, boat, and weapon operations.

The ORPHEUS® system has been enhanced to incorporate additional operation plots as well as incorporating enhancements to the presentation of the information. Other enhancements, such as those requested by the Royal Navy following the demonstrator trial, are the inclusion of statistics, structural monitoring as well as user defined limits on the polar plots.

The wave environmental input was done by hand on the initial system. From the trial the UK Navy operators were found to be good at estimating wave height but not so accurate at estimating modal period. They could however, calculate encounter period very well, so algorithms were included to calculate the modal period from their encounter period input. Current developments include incorporating automated environmental input and Quiescent Period Prediction into the system to further enhance its capabilities.

6. ORPHEUS AT SEA

Since the 2005 development project, ORPHEUS has been installed on a number of Type 23 frigates and integrated with the existing structural strain gauging data logs. Further vessels are planned for during 2006 as well as linking it into the simulator and computer based training facility.

7. SUMMARY

A team within QinetiQ Platform Support Services Group has developed ORPHEUS, a unique navigational safety tool initially developed for Royal Navy ships.

ORPHEUS, an acronym for Onboard Risk Performance Hazard Evaluation System, is a dedicated and flexible operator guidance tool that provides clear and concise information on how a ship will perform in a variety of weather scenarios.

The Royal Navy has a continuing need to provide ship handling training for watch keeping officers and specialist navigators. QinetiQ's development of classroom programs and ORPHEUS has already delivered improvements in hull design and understanding platform behaviour in extreme sea conditions. Harnessing the capabilities of these programmes to enhance both training and guidance at sea can only result in improvements in operational capability, increased safety and availability, lower through life costs, more competent operators and better management of risk.

ORPHEUS has now been installed on a number of frigates within the RN fleet after initial trials onboard their sister ship, HMS *Marlborough*, proved a veritable success.

The benefits of the ORPHEUS® system can be summarised as:

- Provide the operator with the means to minimise the risk of ship survival in extreme weather
- Provide the operator with the means to minimise the risk of damage to the ship in heavy weather.
- Increase the operational envelope and/or improve operational safety of most shipboard tasks that are degraded by ship motions caused by the presence of rough weather, such as aircraft operations, UXVs, towed array/towed body deployment, small boat operations and weapons firing.
- Aid ship operators to maximise crew comfort and crew effectiveness.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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