Maritime and Coastguard Agency

MARINE GUIDANCE NOTE

MGN 327 (M)

Research Project 502: High-Speed Craft Dynamic Stability in Following & Quartering Seas - Design Guidance

Notice to all Naval Architects, Designers, Consultants and Owners of high-speed craft

This notice should be read with the applicable High Speed Craft Code

Summary

RESEARCH PROJECT 502 – HSC Dynamic Stability in Following & Quartering Seas

RESEARCH CONTRACTOR: BMT SeaTech Ltd

TIMESCALE: 2.7 years

EXECUTIVE SUMMARY:

Many high-speed craft (HSC) are known to suffer from problems of control in following and quartering seas, including behaviour such as surfing, bow-diving and broaching. The purpose of this research project was to study the currently available literature on the subject, and identify and conduct further research where this was considered necessary, concentrating on the dominant types of HSC currently in service.

Captive and free-running tests were conducted on a models of monohull, and conventional and wavepiercing catamaran HSC. These have been used to develop a mathematical model to aid understanding, and develop guidelines for the design and operation of HSC to minimise vulnerability to loss of control and/or stability.

The purpose of this Guidance Note is to summarise the guidance to designers.

1 Background

1.1 Most types of high-speed craft (HSC) are known to experience some degree of difficulty of control and/or reduction of stability in following and quartering seas, and no guidance specific to such vessels is currently available for designers on how to avoid or mitigate these effects. Surfing, bow diving or broaching in following and quartering seas may lead to violent motions which present a hazard to the craft and its occupants.

1.2 The purpose of this project was to gain an improved understanding of these phenomena as they affect high-speed craft, and so to provide guidance to both designers and operators.

1.3 The purpose of this Guidance Note is to summarise the guidance to designers.

2 Hazards

High-speed craft are exposed to the following hazards in following and quartering seas:

2.1 Surfing, when the craft is accelerated by the crest of a following sea, and directional control is temporarily lost.

2.2 Bow-diving, when a craft moving faster than the waves immerses the foredeck, leading to rapid deceleration and possible structural damage and injury to personnel.

2.3 Broaching, when the crest of a wave picks up the stern and causes it to shear off course, leading to temporary loss of directional control

3 Hullform

3.1 The combination of a fine bow and a broad stern, in a vessel that is moving at speed down-wave and experiencing significant yaw motions, has been found to be most vulnerable to broaching in following and quartering seas. In the model test series, the wavepiercing catamaran was a clear example of a fine (centre) bow that frequently buried itself in a wave crest only for the broad stern to be lifted by a quartering sea, resulting in an uncontrollable broach.

3.2 High-speed craft are designed to be lightly loaded, and this leads to shallow draught. If the shallow draught, especially at the stern, is combined with significantly large above-water hull volumes and windage, behaviour in following and stern quarter seas is often compromised. This is because a following or stern quartering wave can act on the above-water volume and lift the stern bodily once the craft deviates from directly down-sea by more than a few degrees. Shallow draught allows this to happen more readily; a quartering wave can move the stern laterally and set up the yaw motions leading to a broach.

3.3 Design features, such as fixed fins or deadwood, which improve directional stability also improve behaviour in following and quartering seas.

4 Bow Design

4.1 The freeboard at the bow is critical to the susceptibility to bow-diving. This is especially so for catamarans which, having a cross-deck forward, can be a severe, if not catastrophic event, since greater quantities of water can accumulate on the foredeck.

4.2 A single criterion for adequate freeboard at the bow has not been found. A Scandinavian rule of thumb is that the freeboard measured to the wetdeck at 5%L_{BP} abaft the tip of the bow should be greater than 85% of the wave height most likely to be encountered.

4.3 However use of the mathematical model developed as part of this project indicates that bow-diving can occur in waves of critical length and at critical speed with wave heights as little as 45% of the bow freeboard (to the deck). There is one report of an actual bow-dive where the wave height was only 25% of bow freeboard.

4.4 The same mathematical model indicates that increased buoyancy in the forebody for the same bow freeboard produces only a limited improvement in vulnerability to bow diving. Whereas increasing freeboard by re-spacing the hull waterlines produces a substantial improvement.

4.5 The large amount of additional buoyancy provided by the centre bow on wave-piercing catamarans are very beneficial in preventing very severe bow diving and in none of the model tests, captive or free-running, did a bow dive occur with the wave-piercing catamaran model.

4.6 Measures such as camber that enable water to drain from the foredeck quickly are beneficial. If fitted, bow bulwarks should have very generous freeing ports, but guardrails are preferable. Where bow bulwarks are fitted, they should slope forwards at the bow, as a rearward slope will help to initiate a bow dive.

5 Propulsors

5.1 The monohull model was tested with both waterjet and propeller propulsors. A significant reduction in control in following seas was apparent when waterjets were fitted.

5.2 The installation of waterjets led to a reduction in directional stability and a consequent reduction in control. Although significant yaw motions occurred when a model had a propeller/rudder stern arrangement, control was found to be more positive and likely to allow a more rapid recovery of the situation.

5.3 Furthermore, it was apparent that in a broach, the up-sea waterjet was prone to ventilation, with consequent reduction in the ability to turn back onto the intended course. Propellers were less vulnerable in this respect.

5.4 On those vessels propelled by waterjets some arrangement of passive fixed fin arrangement aft is helpful in improving directional stability. There may be some slight speed penalty in moderate or calm weather, but the probable advantages in a seaway should outweigh this disadvantage. Properly designed fins would minimise any drag increases. The size of such fins should be generally similar to the shaft brackets for an equivalent propeller-driven craft.

More Information

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