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Paper Title:

Avoiding and Solving Problems in Motor Yacht Design

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Abstract:

A large motor yacht is a highly complex system, frequently incorporating new concepts and ground breaking technology, and the potential for problems is very high. Recent projects by the Wolfson Unit have addressed issues with powering, seakeeping, manoeuvring, noise, vibration, back pressure of underwater exhausts, trajectory of above water exhaust plumes, wind comfort on deck, and structural failures. These examples demonstrate the wide range of performance aspects that come within the Unit's field of marine technology, hydrodynamics and aerodynamics. The report will touch on a variety of design and operational problems frequently encountered in motor yachts, the relative testing procedures adopted at the Wolfson Unit and the proposed solutions.

Keywords: model testing, marine technology, hydrodynamic, industrial aerodynamic.

1.1 Introduction

The Wolfson Unit is a marine consultancy with over 40 years of experience in using model tests and trials to address design and operational problems with motor yachts. Problems may be highlighted during the design stage if a model test programme is conducted to address the appropriate issues, perhaps because the designer or owner has some concern over a particular aspect of his design. Frequently, however, the work comes after the yacht has been delivered, and tests are used to find an effective solution to some unacceptable characteristic of its performance. Such troubleshooting projects can be very interesting for the experimenters, but of course are highly embarrassing for the designer, owner and builder. Although some of the proposed solutions can be implemented at a low cost, particularly those which lend themselves to retrofitting, much time, money and effort could have been saved by identifying and solving the problem prior to construction.

2.1 Design Problems

Many shortcomings of a motor yacht design can be highlighted at model scale, in the controlled environment of a towing tank, manoeuvring basin or wind tunnel. For example, the Wolfson Unit has conducted wind tunnel tests on yacht superstructures to help increasing the levels of wind comfort around deck seating areas and outside helm positions, or to assist the designer in complying with the requirements for helicopter flight decks. Figure 1 illustrates the problem that may occur with exhausts from funnels above the superstructure. Adjustments to details of the funnel structure eliminated the problem.

Another area where tests at model scale prove advantageous is the assessment of the manoeuvring characteristics of a yacht. The Wolfson Unit have conducted several manoeuvring programmes on radio controlled models, or 'free-running tests', in order to investigate the directional stability of a yacht and the influence of factors such as Vertical Centre of Gravity (VCG) height or rudder angle. Examples of the tests conducted within free-running programmes are turning circles, zig-zag tests, spirals, reverse spirals and dynamic heel angle tests.

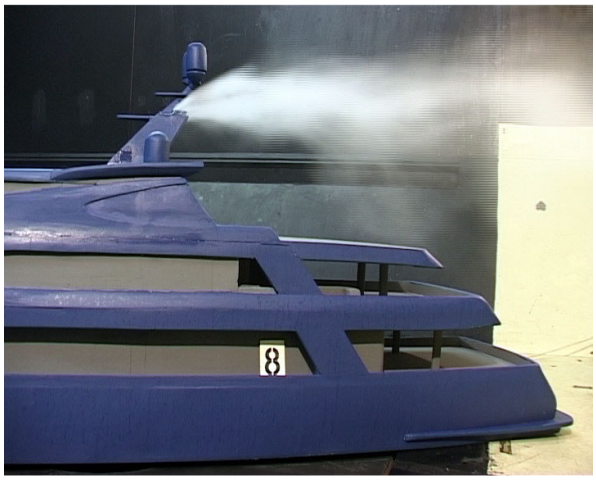

Fig.1 – Exhaust plume trajectory interfering with the aft end of the sun deck

Fig.2 – Manoeuvring tests on a model Patrol Boat for Colombo Dockyard Ltd.

2.2 Operational Problems

The performance of a vessel may have been satisfactory during trials or towing tank tests, factors such as seastate, displacement or positioning of the centre of gravity may affect the seaworthiness or comfort of the newly built yacht. Many Owners and Captains suffer discomfort and even structural or mechanical failures, in the belief that the problem is unavoidable. However, a simple, low cost solution can often transform the yacht's operation without affecting its styling. One example is the option of retrofitting bilge keels to reduce roll motions: as shown in Figure 3, such appendages may help reducing the roll response by 40% at the yacht's natural roll period. A further positive effect consists in shifting the roll resonant frequency, giving the yacht a longer natural roll period. Model testing carried out at the Unit demonstrates that large keels would not bring a heavy resistance penalty, provided that they are properly aligned to the flow along the hull.

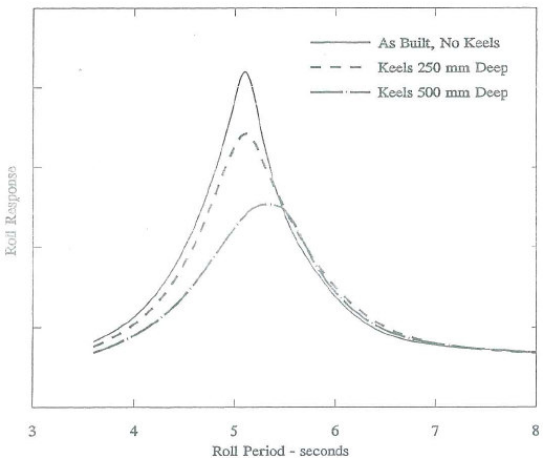

Fig.3 – Variation of roll response with bilge keel depth. Data derived from model tests on a 41 metre motor yacht.

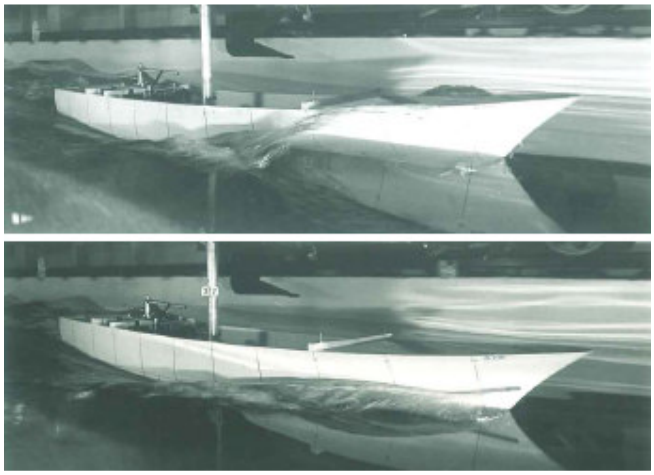

Fig.4 - 1:18 scale model, tests at 17Kn in waves of 1m significant height: no spray rails fitted (top), spray rails (bottom)

Towing tank testing can advantageously be used when a yacht experiences problems with deck wetness and visibility. These can often be eliminated with the introduction or increase in size of bow spray rails. The sequence of photographs in Figure 4 shows a model under test with and without spray rails. This motor yacht was very wet in even a modest sea state, where green water and spray was above the bulwarks, but with a spray rail fitted it was completely dry. The tests enabled the rail to be fitted in the confidence that its location

would give good performance in the expected sea conditions, while minimizing the visual impact on the styling of the yacht. The spray rail as fitted was just 100mm full scale.

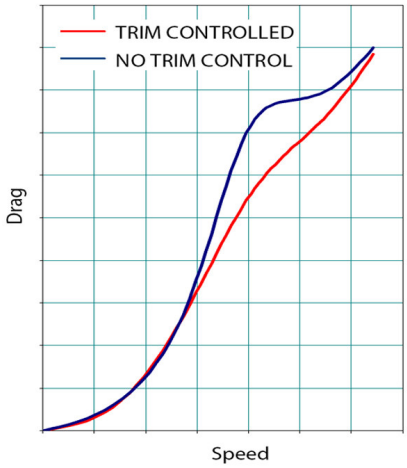

Fig.5 - effect of trim control devices

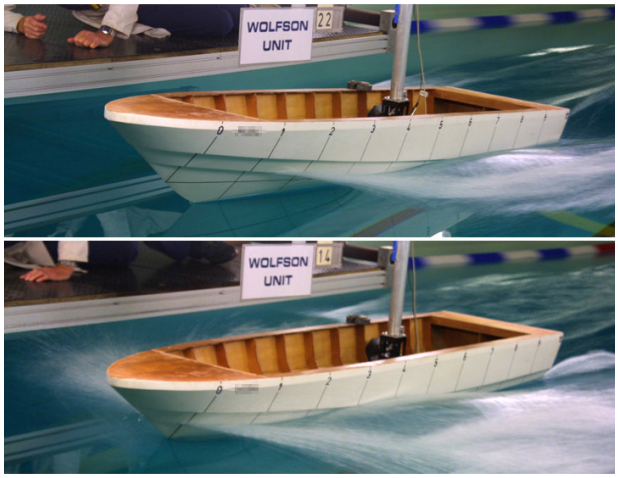

Fig.6 - tests at 30Kn, different interceptor depths:
no interceptors fitted (top), 40mm interceptors fitted (bottom)

Figure 5 shows that optimisation of running trim through the use of interceptors or trim tabs can greatly reduce the required power throughout the speed range, especially around the main resistance hump region around hull speed. This can be especially important for water jet driven vessels where the efficiency of the propulsion system around hull speed is low and consequently without trim control the vessel may not be able to reach top speed. The unit has optimised the running trim of hundreds of vessels using trim control and more recently, parts of the industry have adopted stern mounted topside interceptors for vessel course keeping.

As the quality of finish, and expectations of owners, increase, noise and vibration are becoming increasingly important in developing a vessel. Exhaust and engine noise are already subject to legislative requirements under the RCD, and the expected levels on large yachts are significantly lower than those limits. The Unit has long been associated with troubleshooting on vessels experiencing vibration from propulsion machinery, as well as hydro dynamically induced noise, solving problems by re-designing propellers, altering intake flow characteristics, and modifying keel trailing edge shapes. Now, by joining forces with the world renowned Institute of Sound and Vibration, also situated in Southampton University, and specifically with engineers with significant automotive experience, where noise and vibration engineering is significantly advanced, the Unit can offer not just retrospective advice, but can offer assistance through the full project cycle.

3.1 Conclusions

The full version of the report will present a variety of design and operational issues frequently encountered in motor yachts. In each case, the testing procedures adopted at the Wolfson Unit and the proposed solutions are presented. When appropriate model test programmes are conducted, problems may be highlighted during the design stage. For example, results of wind tunnel tests on yacht superstructures may prompt the designer to revise the layout of a deck, in order to increase the levels of wind comfort around seating areas. More frequently, some unacceptable characteristic of a yacht's performance become apparent only after the yacht has been delivered. If this is the case, tests can still be used to find a cost-effective solution. For example, a well-designed towing tank programme can help reducing deck wetness or optimising running trim. Such examples demonstrate the wide range of performance aspects that come within the Unit's field of marine technology, hydrodynamics and aerodynamics.

4.1 References

1. Deakin, B. Refinement of Yacht Superstructures with the Aid of Wind Tunnel Tests. Project USA Conference, Fort Lauderdale, Florida, April 2003.
2. Wolfson Unit Report No.608, Model Tests to Develop an Arrangement of Bilge Keels to Reduce the Rolling Characteristics of the motor yacht AETEA, 1984.

Barry's short CV

Barry joined the Wolfson Unit in 1978, and has worked in three principal areas: ship testing, stability and industrial aerodynamics. In recent years he has specialised in stability and safety and has earned an international reputation for his work on small craft stability. He has managed the projects conducted for the MCA (LINK) and acted as an expert witness in arbitrations, civil cases and coroners' inquests. He is a member of a number of committees concerned with stability and safety, and has presented papers on the subject at many international conferences, and to the IMO. He was awarded the Royal Institution of Naval Architects' Silver Medal in 1990 and their Medal of Distinction in 2006.

Matteo's short CV

Matteo joined the Wolfson Unit in 2007, having obtained an MSc in Mechanical Engineering at the University of Perugia, Italy and completing a PhD on race modelling programs under the joint supervision of the Universities of Southampton and Perugia. The findings of his research have been presented at international conferences, including the Chesapeake Sailing Yacht Symposium, HISWA and the 'Modern Yacht', and published in academic journals. Since joining the Wolfson Unit, he has been working on commercial contracts and the development of software such as HST, the Unit's hydrostatics and stability package.

Wolfson Unit MTIA

With its experienced staff of engineers, the Wolfson Unit operates a consultancy service in yacht design, ship design, small craft design, naval architecture, marine technology and industrial aerodynamics, providing Tank Testing, Wind Tunnel Testing, Consultancy, Design Software and Innovative Research to a worldwide customer base.

The Wolfson Unit for Marine Technology and Industrial Aerodynamics is part of the Research Institute for Industry in the School of Engineering Sciences at the University of Southampton. It also operates in collaboration with the Department of Engineering and Naval Architecture at the Southampton Solent University.

For more information on our background and our range of services, please visit our website www.wolfsonunit.com