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A viable approach to propeller safety for small craft: Ringed Propellers

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ABSTRACT

It is well known that conventional outboard propellers are very dangerous to humans and marine life.

One commonly used alternative is to fit a guard around the propeller, fixed to the outboard leg or skeg. However, this results in a significant reduction in performance and, as the projected area is increased beyond the diameter of the propeller, can be deemed to increase the probability of an impact – which can also be deadly when travelling at speed.

This paper briefly discusses the design of ringed propellers for outboard motor applications, including the contribution of CFD and empirical testing, including full scale test results.

It also discusses injuries that can be caused by outboard propellers and, in particular, recent research comparing injuries caused by conventional propellers with those of ringed propellers under similar conditions.

The paper concludes that ringed propellers show significant performance advantages over guards and overall safety improvements over open bladed propellers and that they could therefore potentially become a best practise option for safer boating.

Keywords

Propeller
Ring
Injury
Safety
Guard

1 INTRODUCTION

The dangers of conventional propellers have long been apparent, particularly where small craft come into close proximity to swimmers or marine life, such as Florida’s manatees. The issue is the subject of a number of safety campaigns including, in recent years, one conducted by the US Coast Guard (“You’re in Command” safety campaign, 2007).

Commercial and governmental operators of such craft therefore become exposed to personal injury liabilities – one law suit in particular (Sprietsma vs. Mercury Marine, 1995 - www.law.cornell.edu) even becoming a test case for product liability claims in general in the US.

For outboard engines, various solutions have been proffered to mitigate the likelihood and/or severity of propeller strike injuries, including water pumps, cage guards, ring guards and other cowelled arrangements (two guard designs are shown in figure 1). These devices generally suffer from significant losses in efficiency and, thus, top speed. Other reported disadvantages include cost, maneuverability, the need to bolt them to the engine leg and damage to engines. Even in safety craft applications, guards have often been deemed too slow to be viable, owing to the need to reach a distress situation quickly.

Figure 1 An example of a cage guard and a ring guard

Meanwhile, safety testing data in the public domain for guards, the most commonly used solution of those listed, have proved inconclusive: it has been shown that at higher speeds (greater than 10 mph), any impact can potentially be fatal. Since guards sweep a larger area through the water, it can therefore be argued that they are more likely to cause such incidents. Guards can therefore not be mandated, nor deemed “best practice”, for boats fitted for general use.

On the other hand, ringed propeller designs can be of generally similar diameter to equivalent open bladed propellers (as illustrated in Figure 2, showing a ringed propeller within a ring guard). If they can be shown to be safer at lower speeds and overcome the performance issues, they could be deemed an effective alternative to a conventional propeller and potentially best practice in terms of safety for general boating use.

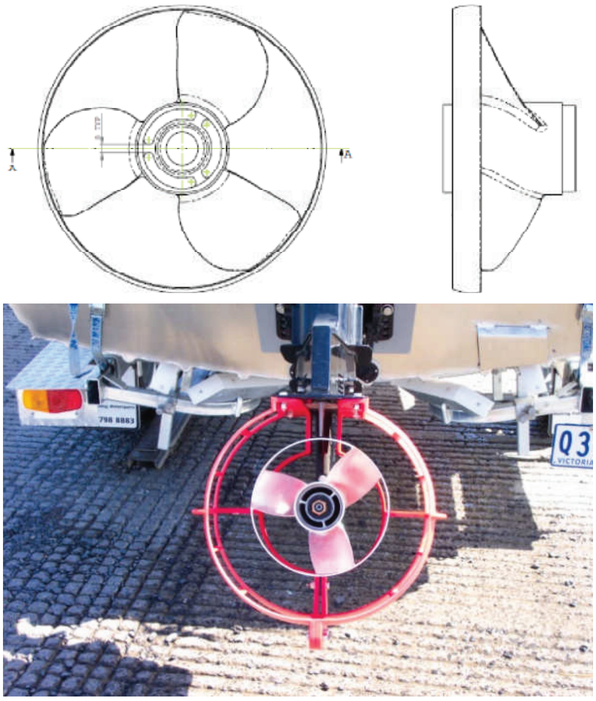


Figure 2 General schematic of ringed propeller and comparison with diameter of a ring guard

2 CONCEPT

Ringed propellers, comprising a cylindrical or frusto-conical ring attached to the tips of radial blades, have existed in various forms, if not been in common use, for at least a hundred years. The purposes of such designs have ranged from protecting blades in shallow waters to attempting to improve efficiency. None of the historical developments to-date has enjoyed sustained use for various reasons, including performance detriment and high stress concentrations leading to failure.

The specific propellers being dealt with here are one-piece designs (with integral hub, blades and ring) for use with, and retrofittable to, the common brands of outboard engine (see figure 3). The development began in the mid 1980s, incorporating cavitation tunnel testing at Marintek and QinetiQ, in the process, and has attempted to achieve performance comparable to that of a conventional propeller.

At the outset, it was assumed that improved safety, compared to open bladed propellers, would be definitively establishable as required prior to commercialization. Specifically, the programme's goal has been to achieve acceleration and top speed good enough to attract a viable market, whilst providing improved safety.

Figure 3 Examples of modern ringed propellers

3 DEVELOPMENT

Cavitation tunnel testing

The initial goal of the development work was to create a series of propellers suitable for a range of outboard/boat combinations. To do this it was first necessary to understand the broad influence of the principal features of the design, as applied across the horsepower range. A series of tests were commissioned at QinetiQ, Haslar, using a 2.4m x 1.2m cavitation tunnel. Two ringed propellers and one conventional outboard motor propeller were tested over a range of advance velocities and cavitation numbers, enabling information to be obtained for a number of different scales corresponding to different horsepowers. (Wiltshire and Miles, 2003).

Figure 4 QinetiQ cavitation tunnel, Haslar, UK

The propellers had hub diameters corresponding to the through hub exhaust systems on modern outboard motors, and utilised a dummy nose cone. They were driven using the standard open water shaft dynamometer, and an outboard leg was not simulated.

These results gave confidence in the concept, and the opportunity to refine the basic geometry.

Full scale testing

All subsequent hydrodynamic testing was done at full scale using an instrumented boat in the National Water Sports Centre (NWSC) at Patterson Lakes, a suburb of Melbourne in Victoria, Australia. This meant that actual results applying to real boats could be obtained directly, and used to fine tune the propeller geometry for each horsepower range.

The NWSC is an ideal location for testing as it comprises a sheltered body of water of uniform depth over 2km long and 100m wide, with a convenient boat ramp. (See figure 5).

Figure 5 Melbourne's National Water Sports Centre

A number of different boats were purchased to represent small planing craft with lengths over the range of 14 to 26 ft. A system of portable water tanks was developed to make it easy to change the loading condition for each boat. Also, a number of different outboard motors with powers in the range of 8 to 225hp were purchased to represent all the major outboard motor manufacturers. These were all readily interchangeable on the different hulls to speed up the testing process.

A portable instrumentation package was developed to enable the boat speed (radar gun and GPS) and engine rpm to be logged simultaneously. Forward and reverse bollard pull tests were also conducted.

To take into account changes in environmental conditions each test program was repeated with a number of 'standard' propellers, and the results calibrated.

The test program required over 100 designs to be manufactured: most of these were CNC milled from 3D CAD models (see image below) supplied from the Melbourne office, either from solid billet or near-net-shape blanks cast using ureal moulds and some were tooled for larger scale manufacture. (Figure 6).

Figure 6 Ureal moulds for blank casting and prototype machining

In addition, testing was carried out with a variety of ringed propellers in Michigan and Florida states in the USA on a wider variety of craft and in different conditions to establish wider performance benchmarks, including more qualitative tests such as ventilation and performance in weed-infested water.

Computational Fluid Dynamics

A Computational Fluid Dynamics (CFD) capability was developed in parallel with the full scale testing. Results were calibrated against previous empirical cavitation tunnel data as well as, more qualitatively, full scale test information. The analysis, although not predicting cavitation performance, proved able to guide development and rank designs, thus dramatically accelerating design iteration. Typical output is shown in figure 7

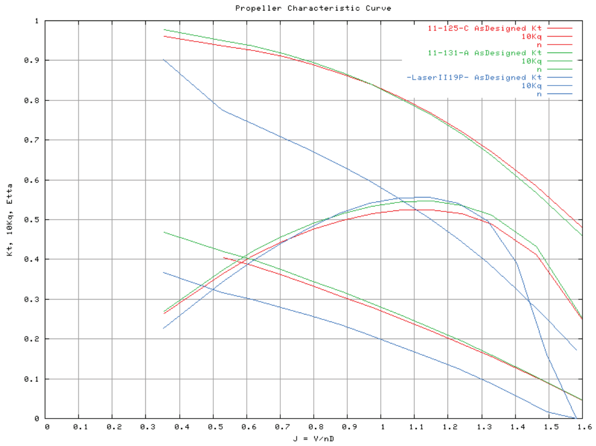


Figure 7 CFD Data from development programme

4 RESULTS

Performance tests

Figures 8 and 9 show acceleration plots taken from tests conducted at Melbourne's National Water Sports Centre for two planning vessels, a RIB and an aluminium hulled boat, showing a direct comparison between a conventional propeller, a ringed propeller and a ring guard (Morley 2006).

In both cases, the ring guard showed a reduction in speed of approximately 30%. The ringed propeller, however, showed a reduction of only 2.3% in the case of the RIB (50hp) and 8.8% in the case of the aluminium boat (90hp). These results are generally typical of similar tests carried out in this programme, although other designs of guard were not included.

The bollard pull results show very little difference between the three configurations, both in forward and reverse. The RPMs achieved are shown in table 1: for reverse bollard pull, in all configurations, the maximum thrust is achieved at a mid-throttle position due to ventilation as exhaust gases are drawn into the propeller disc.

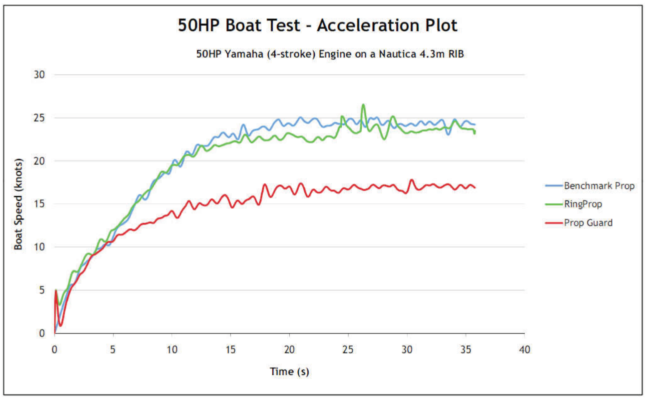
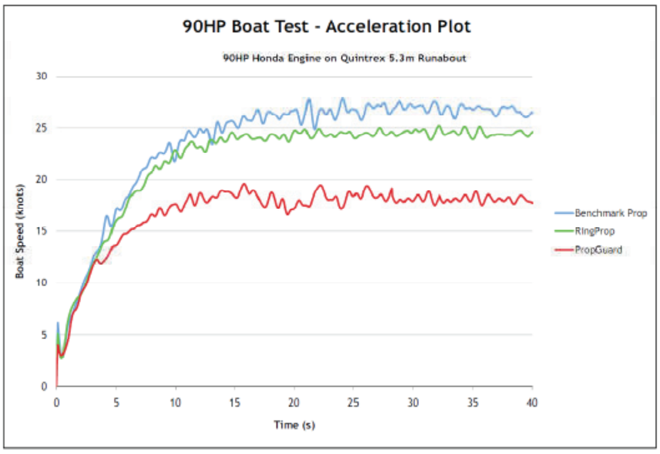


Figure 8 Performance using 50HP Yamaha outboard



	FORWARD SPEED SUMMARY			REVERSE BOLLARD PULL		FORWARDS BOLLARD PULL	
Propeller	Speed (knots)	Engine (RPM)	Reduction (%)	Thrust (kg)	RPM	Thrust (kg)	RPM
Black Max 19P	26.8	5060		118	2500	347	3005
Ringed Propeller	24.5	4980	8.8%	120	2500	352	3925
BM19P + Prop Guard	18.2	4180	32.3%	110	2400	359	3200
BM17P + Prop Guard	18.5	4560	31.1%	117	2600		

Table 1 Performance on 90HP Honda outboard

In testing in Michigan, it was found that entrapment in weed, and the ensuing ventilation caused, was significantly less severe for the ringed propeller than for the conventional propeller being tested (Chapple, Morley,Strykers Marine, 2005). The tests were predominantly conducted using a variety of house boats.

Safety testing

An engineering team from BEST (Biomechanical, Ergonomic and safety Technologies) was commissioned in 2006. This organisation has expertise in engineering safety, injury prevention, biomechanics and human factors including advice on personal injury liability as well as experience in conducting tests relating to propeller guards (Kress 2006).

A facility and technical team was contracted at CRESE (Center for Research and Education in Special Environments) of the University of Buffalo, using an driven radial arm converted to carry a gantry, onto which was fitted a 50hp Honda outboard engine, around an annular water tank (figure 10). A remote actuator was attached to the throttle such that both forward speed and engine revs could be controlled independently to simulate different craft at different speeds.

Figure 10 CRESE annular tank

Suitable target specimens were selected, including pigs, and these were tethered in front of a viewing window on the side of the tank. High speed digital video was taken of the impacts and the target then removed for formal forensic examination and digital still images recorded. A systematic series of tests, using a conventional aluminium Honda propeller and an aluminium ringed propeller in paired impacts, was undertaken to simulate low speed incidents (10mph and below).

A test specimen is shown tethered prior to impact in figure 11, as well as a tell-tale pattern of slices suffered by another specimen caused by the conventional propeller.

BEST found that: “Experimental date indicated that if a human is impacted at low speeds, i.e. below approximately 10 mph, the [ringed] propeller causes less soft tissue and bone damage than a standard propeller. In some instances, the comparison between the soft tissue and bone injuries resulting from an impact by a [ringed] propeller verses a standard propeller may mean the difference between life and death, respectively.” (Kress, 2006)

Figure 11 test specimen before and after impact

5 CONCLUDING COMMENTS

The performance of the ringed propellers tested, in terms of speed (and efficiency), show a significant improvement over that of the guards tested. Also, the performance deficit compared to conventional propellers may be small enough to represent a viable alternative for a large proportion of boat users.

In addition, it appears that the relative safety has been established for low speed accidents while there are no arguments known by the authors to suggest that ringed propellers should be more dangerous than conventional propellers at higher speeds.

The combination of these two points, together with the ease of retrofitting to existing installations, could potentially establish the ringed propeller as a best practice option for safer boating.

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