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NOISE FROM COMMERCIAL SHIPPING AND ITS ADVERSE IMPACTS ON MARINE LIFE

Reducing underwater noise pollution from large commercial vessels

Submitted by the International Fund for Animal Welfare (IFAW) and Friends of the Earth International (FOEI)

SUMMARY

Executive summary:	The incidental introduction of noise from commercial shipping operations into the marine environment has potential adverse impacts on marine life. A review of technologies that may be used to reduce underwater noise output from the loudest commercial vessels was conducted by Renilson Marine Consulting Pty Ltd. The scope of the study was guided by discussions of the Correspondence Group established at MEPC 58. Since cavitation noise dominates the underwater noise signature of large commercial vessels, those that suffer from excessive cavitation will be the noisiest. Cavitation may be reduced by improving propeller design and wake flow into the propeller and a variety of technologies exist to do this. Some of these can be retrofitted as well as incorporated into new build. The review identified scope to quieten the noisiest ships using existing technology without reducing their propulsive efficiency. Some technologies that improve efficiency may also reduce noise and operating costs over the lifetime of the vessel. The Committee is requested to consider the additional research needs identified in this report.
Strategic direction:	7 and 13
High-level action:	7.1, 7.2
Planned output:	1.1.2.3
Action to be taken:	Paragraph 17
Related documents:	Resolutions A.989(25), A.982(24), A.900(21), A.720(17) and A.468(XII); MSC/Circ.1014; MSC 84/INF.4; MSC 83/28; MEPC 59/19; MEPC 58/19; MEPC 57/INF.4 and MEPC 57/INF.22.

Background

1 There is increasing concern about the effects of underwater noise on marine life. A major contributor to this is the noise generated by shipping. Accordingly, MEPC 58 approved the inclusion of a new high-priority item in the work programme of the Committee on "Noise from commercial shipping and its adverse impact on marine life" and established a correspondence group under the chairmanship of the United States to progress work on this issue. The International Fund for Animal Welfare (IFAW) commissioned a review into technologies that may be used to reduce the underwater noise output from the loudest commercial vessels in order to allow more detailed investigation of some of the issues raised in the Correspondence Group. The review was conducted by Dr Martin Renilson of Renilson Marine Consulting Pty Ltd. The full report is available at www.ifaw.org/oceannoise/reports.

2 The objectives of the review were to examine the range of possible technologies that might be used to reduce underwater noise output from the loudest commercial vessels for both new build and existing vessels; to consider design or operational factors that might lead to particularly high noise output; and to consider the likely implications of noise reduction in terms of initial cost, operating costs, effect on vessel handling and fuel efficiency for each identified technology.

3 It appears that there is considerable difference in the noise propagated by the noisiest and the quietest conventional merchant ships (excluding those designed specifically for low noise). Simple calculations suggest that the overall contribution to ambient noise from shipping is dominated by the noisiest vessels. These are also the vessels for which it is likely that noise reduction measures will be the most effective. The dominant feature of these noisiest merchant ships is cavitation associated with the propeller. The study therefore had a deliberately narrow focus on ways of reducing cavitation of noisiest vessels mainly by improving propeller design and wake flow into the propeller. However, additional factors, such as vessel load condition and speed were also considered.

Propeller cavitation and noise output

4 Although there are limited data on the hydro-acoustic noise output for large merchant ships, and the factors that lead to high noise levels, it appears that differences in noise levels are of the order of 20-40 dB (Carlton and Dabbs, 2009). Thus there is likely to be potential to reduce the noise generated by the noisiest ships.

5 It is almost certain that these noisiest ships suffer from greater levels of noise generated by cavitation than other merchant ships. Much of the research into creating quiet ships for military and research purposes has concentrated on reducing noise at speeds below cavitation inception speed, and on raising the cavitation inception speed as high as possible. These measures may not be the most appropriate for large merchant ships because of some loss in efficiency. There has been relatively little attention given to reducing the noise generated by cavitation, but this is the critical issue for reducing the noise generated by large merchant ships.

6 There is little known about what aspects of cavitation generate different levels of noise. It is clear, however, that for merchant ships it is necessary to accept a certain level of cavitation, as this gives a more efficient propeller than one designed to eliminate it altogether. Excessive cavitation can, however, result in extreme vibration, and/or cavitation erosion, which, in some cases, require remedial action. It is assumed that vessels with these problems are likely to represent the noisiest merchant ships. However, at this stage there are few data to confirm this and further investigations relating to cavitation extent and underwater noise levels are recommended.

Vessel speed

7 Most merchant ships will suffer from cavitation as they will be operating above the cavitation inception speed. If these ships were all to operate below this speed then the hydro-acoustic noise levels would be reduced considerably. However, as cavitation inception speed is likely to be around 10 knots, or lower, for many merchant ships, this is clearly impractical. Although there are limited data on the effect of speed on the hydro-acoustic noise generated by merchant ships, it is clear that, in general, for a ship fitted with a fixed pitch propeller, reducing the speed reduces the noise. It is recommended that further full-scale trials be conducted to investigate the effect of speed on hydro-acoustic noise across a range of vessel types. However, on the basis of the existing data it is possible to say that, with a few possible exceptions (such as ships with controllable pitch propellers), reducing speed will reduce noise for the vast majority of large merchant ships.

Vessel load condition

8 Propellers are generally designed for the full load condition. However, few ships spend all their time at the full load condition. Likewise, for a range of practical reasons the ship is never really loaded close to its full load condition when in ballast. Consequently, the propeller is much closer to the surface and, in fact, the tip of the propeller will often be above the waterline. As cavitation is dependent on the actual pressure on the blade and as this will be lower, due to the smaller hydrostatic head, cavitation is likely to be significantly worse for a vessel in ballast than in full load. Also, as ships are designed for full load condition, it is this condition that the wake field is studied, and used for the propeller design. As the wake field will often be considerably less uniform for a ship in ballast this will further increase the cavitation extent on the propeller.

Improving propeller design

9 Improvements in propeller design, either by modifying the existing propellers, or by fitting new propellers designed with noise reduction in mind, have the potential to reduce hydro-acoustic noise for the noisiest merchant ships and increase propulsive efficiency. As ships often operate in different conditions to those predicted at the design stage, it is quite likely that if the propeller were redesigned to suit the actual operating conditions this would result in an improved propulsive efficiency, as well as reduced hydro-acoustic noise. Depending on the changes required, the existing propeller could be modified, or a new one manufactured and fitted at the next scheduled dry dock. In addition, there are a number of different propeller design concepts that have been developed by various proponents, normally with the express purpose of increasing propulsive efficiency and/or of reducing pressure pulses and associated hull vibration (e.g., high skew propellers; contracted and loaded tip propellers; Kappel propellers; New Blade Section propellers). It is not known how these concepts will influence hydro-acoustic noise, however, available data suggests that it is very likely that one or other of these concepts would also have this effect. Such a propeller could be fitted at the next scheduled dry dock.

10 Similar considerations apply for propeller hub cups (e.g., Propeller Boss Cap Fins and Propeller Cap Turbine) which aim to reduce the magnitude of the hub vortices. A recent investigation has shown how properly designed hub caps can reduce the hub vortex cavitation, and consequently the hydro-acoustic noise, as well as improving propeller efficiency, particularly for controllable pitch propellers (Abdel-Maksoud *et al.*, 2004). It is not expected that a specially designed hub cap would substantially increase costs.

Improving wake flow into the propeller

11 The propeller operates in a non-uniform flow behind the ship. Although designers attempt to provide as good a flow to the propeller as possible, this is clearly limited by the desire to have as full a hull form as possible, to increase the carrying capacity of the vessel. Improving the wake into the propeller will reduce cavitation and probably also increase efficiency. There is the potential to improve the wake flow into the propeller for existing ships by fitting appropriately designed appendages, such as wake equalizing ducts, vortex generators or spoilers. These devices can generally be retrofitted, either during a special docking, or during a routine docking, or can be included in the initial design. The technology exists to do this, and although there is some understanding of the improvement that these devices will have on propulsive efficiency, there is little knowledge about how they will reduce the hydro-acoustic noise. However, it does seem very likely that they will do so, particularly for vessels with poor wake flow which are also likely to suffer greatest levels of cavitation.

Costs for retrofitting

12 The costs associated with retrofitting, such technologies into an existing ship, will depend exactly on what is required and on whether it can be carried out during a scheduled dry docking, or if it will need a dedicated dry docking. For example, the costs associated with retrofitting a 20,000 dwt containership will be in the range of US$250k to US$700k, and those associated with retrofitting a 250,000 dwt tanker will be in the range of US$600k to US$2,800k. The increase in efficiency could result in annual fuel savings that could payback initial costs within one or two years.

New ships

13 For new ships, propeller functioning and the wake flow can be improved by more careful design, which will require an increased design effort, including careful model testing and computational fluid dynamics analysis. For ships which spend time in ballast, this work should be extended to include optimization of the propeller design and wake flow in that condition. This extra effort will cost more, however, it is likely to result in improved propulsive efficiency as well as in reduced hydro-acoustic noise.

Conclusions

14 Based on the current review, it is likely that the noisiest ships can be quietened using existing technologies without reducing their propulsive efficiency and with a good chance that initial costs could be recovered within one or two years. Careful propeller design and careful hull design are essential prerequisites to improving the cavitation performance but, even for many new builds, there is not sufficient emphasis in the design effort put into such aspects, which it is assumed is the reason for many ships being noisier than others. It is important to note that the greatest improvements are likely to be achievable for ships operating at sub-optimal efficiency; however, these are also likely to be the noisiest ships. Many of the existing methods to increase efficiency are also likely to reduce hydro-acoustic noise but there is a need for more data on noise levels.

Recommendations for future research

15 The following research recommendations are aimed at gaining a greater understanding of noise related factors to determine whether measures to improve efficiency will also minimize noise. The key research priorities include:

.1 develop a standard method of conducting and analysing full-scale noise measurements, which should be adopted by those making measurements of the noise of conventional merchant ships. This should be coordinated with the work of the ISO Technical Committee on Ships and marine technology, which is developing measurement methods and formats for reporting data on underwater noise from vessels[1];

.2 develop guidelines to help to identify the potentially noisiest large commercial ships. This will require making numerous full-scale measurements on ships where the design features likely to influence noise are known, and relating these features to the measured noise. It will also include an investigation to determine whether large merchant ships which have extreme vibration and/or cavitation erosion, which may require remedial action, represent the noisiest merchant ships;

.3 conduct more noise measurements in cavitation tunnels and full scale, and compare the results to determine the usefulness of conventional cavitation tunnels for noise measurements on merchant ships, and to determine the influence of scale effects;

.4 undertake an investigation into the effect of different types of cavitation on hydro-acoustic noise for a range of typical propellers for large merchant ships; and

.5 conduct independent dedicated acoustic trials to confirm the various claims of noise reduction made by the proponents of the different concepts identified in the report. This could involve testing on sister ships with and without the "improvements", where possible.

16 Other research recommendations are:

.1 undertake an investigation into the effect of non-uniform wake on hydro-acoustic noise generated by a cavitating propeller;

.2 undertake an investigation into the effect of ship loading condition, and proximity of the propeller to the free surface, on hydro-acoustic noise generated by the propeller, including the effect of the tip of the propeller breaking the water surface at the top of the cycle;

.3 undertake an investigation into the best way for combining pitch and rpm control on ships fitted with Controllable Pitch propellers to optimize the hydro-acoustic noise generated, and develop guidelines for this;

.4 conduct controlled full-scale trials to investigate the effect of speed on hydro-acoustic noise for a wide range of different ships and ship types;

.5 undertake an investigation into the relationship between the delivered power required for a given speed to the hydro-acoustic noise at that speed;

[1] See Piersall (2009). When silence means survival – Protecting the marine ecosystem from underwater irradiated noise. *ISO Focus* January 2009: 38-39.

.6 conduct controlled tests in cavitation tunnels on undamaged and damaged propellers to determine the effect that various levels of damage will have on the hydro-acoustic noise generated by the propeller;

.7 undertake an investigation into the effect of propeller coatings on propeller generated hydro-acoustic noise under typical cavitating conditions for conventional merchant ships;

.8 investigate whether it is possible to use hydro-acoustic measurements to assess when the damage to a ship's propeller warrants repair; and

.9 conduct an investigation into the effect of skew on propeller noise for a typical merchant ship under normal cavitating operations.

Action requested of the Committee

17 The Committee is invited to:

.1 take note of this information;

.2 urge IMO Governments and the industry, as a matter of urgency, to address additional research needs identified in this report with a view of reporting back to the Corresponding Group; and

.3 urge IMO Governments to encourage a review of their merchant fleets in order to identify vessels that would benefit most from efficiency improving technologies that are also likely to reduce underwater noise output.

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