PROPELLER LEADING EDGE TRIMMING AND MAINTENANCE EFFECTS ON SHIP'S NOISE OPERATIONAL PERFORMANCES

by

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ABSTRACT

In the last ten years, considerable experience has been gathered at CEIMM's cavitation tunnel (Centro Esperienze Idrodinamiche Marina Militare) on the effects of propeller leading edge geometry on cavitation (and noise) performances. The experience has been gained on both model and full scale tests, carried out by using various techniques. Some considerations are also made on the design, manufacture and maintenance needs imposed by today's silent ship design and operation.

INTRODUCTION

It is well known that a fluid surrounding a lifting surface, with foil type sections, undergoes the most important velocity variations in the vicinity of the section's leading edge (1,2).

During one revolution of a propeller blade, the velocity variations are related to the wake distribution at the propeller disc, the propeller working conditions, and the cavitation number (3, 4).

At the initial propeller design stage, some parameters can be suitably chosen to delay cavitation, viz. low RPM, regular wake field, loading distribution, skew, etc. , (5,6). Although the whole blade geometry is responsible for a given cavitation behaviour, the leading edge is the region where the cavitation first starts and develops. Due to the important correlation between cavitation and noise,(7,8), any operational requirement which implies quietness makes, therefore, the leading edge geometry very important.

Unfortunately, the leading edge region is difficult to shape properly at the production stage, and even more difficult to check and control accurately and maintain efficiently.

In this paper some examples of propeller leading edge geometry effects on cavitation and noise behaviour of both full scale and model propellers are briefly presented and discussed. The analytical illustration of the effects of geometrical details, working conditions and local Reynolds number on the fluid velocity distribution and cavitation onset of propeller blade is not the scope of this paper; considerable literature can be found on this field (9, 10).

1 DESIGN PROBLEMS

When low noise propellers are to be designed, several computer programs can provide rather accurate theoretical predictions on the cavitation and vibration performances of a given propeller geometry operating at given conditions (11).

One fundamental design parameter is the local full scale wake field, still ill known at this stage. Therefore all designs are developed and optimized under some assumptions about the wake field.

The leading edge is the most sensitive part of the blade with respect to both the local wake pattern and the cavitation. Definite risk exists of local unadequacy of the propeller geometry when the wake field shows unexpected variations. However, leading edge trimming can give positive solution to the problem (12).

2 EXISTING STANDARD AND PROPELLER CAVITATION

Propellers manufactured to the tolerances prescribed by the international ISO 484-81 standard will in general have propulsive performances corresponding to the design and model testing stage predictions.

On the other hands, generous tolerances are allowed in those parts of the blade where the cavitation phenomena first occur (tip, leading edge region, blade root region). Sectional thickness distribution tolerances become quite significant at the leading edge. Experience gathered leads eventually to the conclusion that a " case by case " tolerance must be studied and adopted when special quitness is imposed by operational requirements to a given propeller. Production accuracy, according to international standards, does not represent in such cases a sufficient safeguard against cavitation onset.

Propeller geometry check procedures in blade regions where large curvature variations occur, are difficult. Templates can be used only at given positions, and even there the resulting accuracy is at least doubtful.

Check problems exist also for numerically controlled manufacturing. Spot checks are possible by using the same manufacturing equipment, but the necessary quasi-continuous (high density) check is impractical (13).

3 MAINTENANCE PROBLEMS

Low noise propeller maintenance during the operational life of the vessel is extremely important.

The use of grinding machines can be allowed for cleaning flat areas (subject to some precautions). Their use must be absolutely forbidden where local surface curvature variations exist or where air injection systems are used. Frequent maintenance by suitable brushing and compressed air cleaning must be adopted.

A special problem is encountered when geometry check must be performed on ship propeller during drydock. This check should be performed on a routine basis or when local damages occur. Difficulties in carrying out this geometry checks " on the spot " impose disassembly of blades (in a C.P.P) or dismounting of the whole propeller.

4 LEADING EDGE TRIMMING EFFECTS - A SAMPLE CASE

A practical case might well illustrate the leading edge trimming effects on propellers of twin screw naval vessels. During the design and model testing phases, particular care had been paid to propulsion performances optimization, as well as noise and vibration minimization.

Final trials well confirmed predicted performances, but during the stroboscopic tests an unexpected local cavitation phenomenon was observed on the face of the propeller, at the leading edge, when the blades were at an angular position of about 300 degrees (0 degrees upwards) (14).

Accurate checks led to the conclusion that blade leading edges were to be manufactured according to a closer tolerance, and corrective actions were then undertaken. A successive stroboscopic test did show an improvement, but some problems still existed (15).

Studies were then carried out by means of model tests, where wake field scale effects were systematically varied, assuming different scale factors. Local wake effects on cavitation onset were also investigated.

A local leading edge trimming was defined as possible solution : a considerable increase on face cavitation inception speed was expected together with a very slight decrease of cavitation performance of the back and,without modifying in practice, propulsive performances (16).

Model modifications and successive tests at the cavitation tunnel proved such a solution. Fig. 1 shows the maximum extent of modifications. After applying the above modifications to the full scale propellers, sea trials were carried out, and a full confirmation of the model cavitation performance was found. Table 1 gives the cavitation onset Froude number values for various cavitation phenomena before and after the trimming (17).

5 LEADING EDGE MAINTENANCE - A SAMPLE CASE

Stroboscopic tests carried out on board another class of naval vessels, shew a propeller cavitation behaviour somewhat similar to what already mentioned under para 4 above. A very thin, flashing face (and partially back) leading edge cavitation was observed at rather low speeds (Froude number about 0.19),at about 0.5 R of the propeller blades, as shown in Fig. 2, (18). Local defects (scratches) at the leading edge,where cavitation was observed, were found during successive drydock inspection. Dimensions of scratches were about 80 mm long, 2 mm wide, and 2 mm deep. They could have been caused during one of the blades handling and mounting or by cables in mooring or towing operations or to improper maintenance.

Proper corrective maintenance actions, leading to the elimination of such scratches, kept again the cavitation onset speed at the original value (Froude number 0.23).

6 CONCLUSIONS

Stroboscopic tests results gathered during sea trials when compared with theoretical cavitation predictions can show the presence of unexpected local wake disturbancies and/or geometrical inadequacies at the leading edge of the propeller. Corrective actions are possible,in fact the results obtained stressed the importance of both shaping and successive maintenance of the leading edge.

Accurate blade manufacturing and rigorous checking procedures are also necessary. The development and the systematic use of a leading edge geometry measuring equipment (possibly portable) will be a powerful tool for improving the present acoustic performances of silent vessels.

PHENOMENA	ORIGINAL LEADING EDGE	TRIMMED LEADING EDGE
Back sheet cavitation (at leading edge)	0.231	0.231
Face sheet cavitation (at leading edge)	0.207	0.287
Back bubbles	0.415	0.415
Hub vortex	=	0.415

Table 1 - Froude numbers of cavitation onsets

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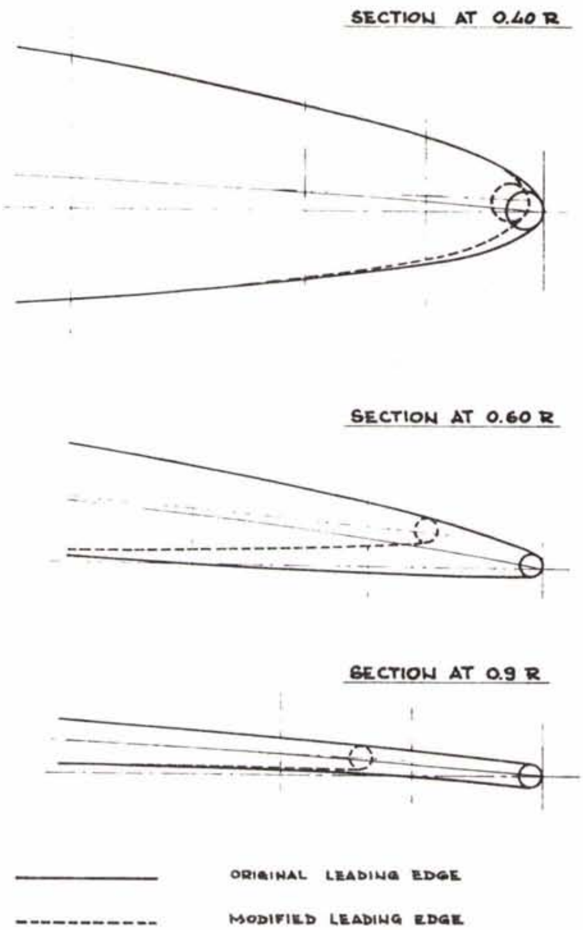
SECTION AT 0.40 R
SECTION AT 0.60 R
SECTION AT 0.9 R
ORIGINAL LEADING EDGE
MODIFIED LEADING EDGE

Fig. 1

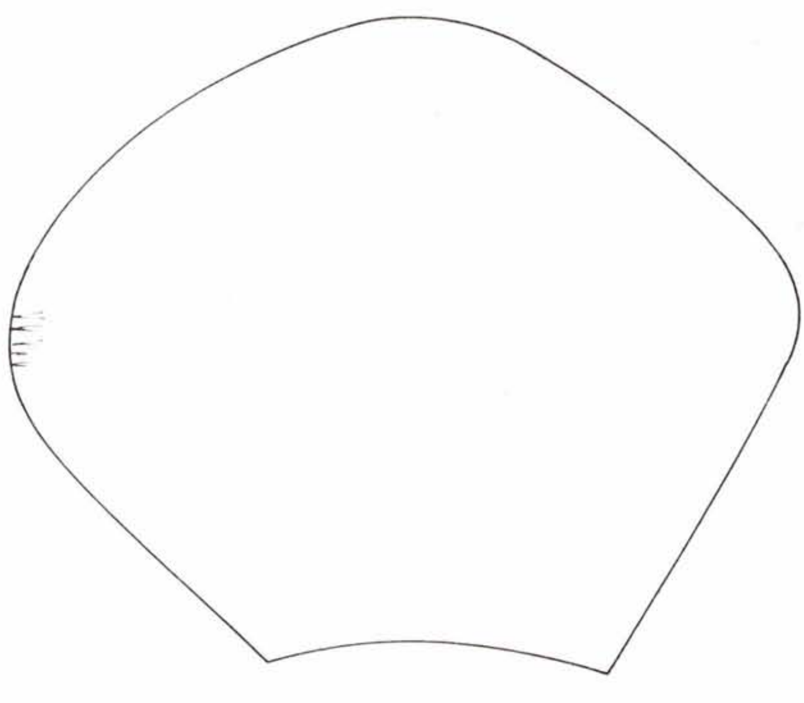

Fig. 2

DISCUSSION

G. Thomas (United Kingdom): What is the significance of Froude number in the context of this study? Is speed the only parameter that is changing?

L. Accardo: The Froude number indicates the increase in ship speed in relation to some other parameters (revolutions, power output, etc.). It has been substituted for ship speed in this unclassified presentation.