The Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships

Committee Chairman: Dr. Michael L. Billet
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1. DISCUSSIONS

1.1 Discussion to the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships by Colin Anderson, International Paint Ltd, United Kingdom

I congratulate the Committee on their fine work on the cavitation erosion of marine propellers, and would like bring to their attention some observations regarding our recent experiences with coated propellers that the Committee Members and participants may find interesting:

International Paint has now painted over 150 commercial and naval ship propellers with Intersleek. This is a silicon-based hydrophobic soft compliant coating that prevents fouling by being “non-stick” (foul release). We have generally found that cavitation causes most detachment of this coating on the suction side, with much less occurring on the pressure side. This would confirm what the Committee discussed regarding cavitation, with the pressure side being far less damaged.

There is evidence in the literature that soft compliant coatings are better for cavitation resistance than hard tough coatings. One explanation for this is that bubbles collapse differently on soft hydrophobic coatings than they do on hard coatings, with the energy being able to be absorbed by the soft coating.

The main reason why ship owners are coating propellers is in order to keep fouling off, so that the efficiency of the propeller can be maintained without the need for any in-water cleaning. This is clearly demonstrated by the propeller coating research conducted by the University of Newcastle sponsored by International Paint as reported in Mutton et al. (2005). From this paper I include two interesting pictures of the uncoated and coated propeller from the Newcastle University’s Research Vessel “Bernicia”. This vessel spends approximately a half of her time in harbour and the other half operating along the North East Coast of England. These pictures may help to appreciate the effect of the Intersleek coating in prevention of fouling.

Figure 1.1- The propeller of “Bernicia” after 14 months in service before coating. Hard shell fouling is present to half the blade radius (Mutton et al., 2005).

Figure 1.2- The propeller of “Bernicia” after 12 months in service after coating. 95% of the coating is intact, except some detachment of the blade edges. Light slime fouling is present on the inner half of the blades (grey material on the red coating is the dried biofilm). This could be easily removed by hand or with a damp cloth (Mutton et al., 2005).

References.

Mutton, R.J., Atlar, M.A., Downie, M.J. and Anderson, C., 2005, “Drag prevention coatings for marine propellers”, 2nd International Symposium on Seawater Drag Reduction, Busan, Korea, 23-26 May.

1.2 Discussion to the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships by Ian W. Dand, BMT SeaTech Ltd, United Kingdom

I have one question, of an editorial nature only, on the Report of the Committee.

The second paragraph of the right hand column on page 515 of the Proceedings appears to have the superscripts “5” and “6” transposed when compared to the Figures (4.1 and 4.2) to which it refers. In other words, Figure 4.1 appears to give a 5th power law, whereas the text says it is a sixth, while Figure 4.2 states a sixth power law, when the text says it is a fifth.

1.3 Discussion to the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships by Do Ligtelijn, Wärtsilä Propulsion Netherlands BV, The Netherlands

The Committee is to be congratulated with their extensive Report on cavitation erosion. Especially since the Report is not only useful in a scientific but also in a practical sense. Concerning the Guidelines to Minimize Cavitation Erosion (pages 531 to 534), and the discussion contributions by Prof. van Terwisga and Dr. Jessup I would like to make some additional remarks. The remarks are related to the distinction of cloud cavitation versus unstable sheet cavitation (Prof. van Terwisga) and face cavitation sometimes not being erosive (Dr. Jessup).

In the EROCAV project, in which our company was a partner, quite some attention was paid to so-called isolated cavitation sheets. Reference is made to the Handbook, Bark et al. (2004). An isolated sheet cavity being a cavity that is not connected to the tip or hub. On a propeller this may typically occur between say 0.5R and 0.8R or so. It was found that isolated sheet cavitaties (both back and face) are responsible for shedding of clouds that will cause erosion when entering a high pressure area downstream As long as this type of cavity is sufficiently 1-dimensional (spanwise extent much larger than chordwise extent), and fulfills a certain lifetime (time between inception and desinence during one blade passage) requirement, the shedding is weak enough as not to cause any erosion. In the EROCAV project several of such cases were observed at full-scale, whereas Dr. Jessup confirmed this also from his experience. So there is a certain nuance possible in the Guideline regarding cloud shedding. The Guideline on unstable sheet cavitation might be taken as specifically referring to sheets that are not isolated, but connected to the tip, or to isolated sheets with a clear 2-dimensional character. The Committee might in that respect even consider describing isolated sheets in relation to a Guideline on erosion risk instead of an explicit cloud cavitation Guideline.

Though the Committee reports on page 513 that composite propellers may have low resistance to cavitation erosion, they may offer certain advantages in avoiding erosion. Basically they offer the possibility to apply more favorable t/c ratios. However, more experience and investigations are needed for instance regarding fast and easy reparability and manufacturing costs. Ship propellers are operating in a hostile environment. Metal propellers usually show all kinds of dents and other leading edge and tip damage after some time in service due to hitting floating debris, trees, ice blocks or touching the ground in shallow waters. Repairs on metal propellers can be done quick and easy in most cases within the time a ship is in for a regular maintenance dry-docking. There is not yet much experience how to do this within the same period of time on composite propellers, unless of course the damaged blade is simply replaced. Regarding production costs it has to be considered that propellers are in most cases “one off” products, whereas presumably the application of composite material would become advantageous for larger series only.

References.

Bark, G., Berchiche, N. and Grekula, M., 2004, “The EROCAV Observation Handbook”, Department of Naval Architecture, Chalmers University of Technology.

1.4 Comments to the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships by Tom van Terwisga, MARIN and Delft University of Technology, The Netherlands

First, I would like to compliment the Committee with their attempt to summarize our joint knowledge in the dark space containing the physics and appearances of cavitation erosion.

1. Scaling laws in cavitation erosion.

A crucial link between fundamental research on a laboratory scale and the real world problems is provided by the scaling laws. However, the review of the state of development of these rules, as presented in Section 4 of the Report, leaves little room for happiness. This becomes especially apparent in Table 4.1, where the pit number rate is given as measured with different techniques. Looking for example at stainless steel-water combination, the exponential value of the local velocity, occurring in the scaling law, varies between values from 4 to 7. Similarly, the exponent values of the volumetric damage rate vary from 5 to 8.

An obvious conclusion from this serious scatter in results is that the fundamental research is still far from helping the maritime industry in making reliable predictions for cavitation erosion rate. This conclusion is however not explicitly drawn by the Committee. Does the Committee agree with this conclusion? And if not, which scaling laws then does the Committee recommend us to believe and why?

A logical consequence of this conclusion would be that the current Committee recommends a next Committee on cavitation to try to find the most reliable scaling laws for application to, for example, the prediction of erosion rate of stainless steel wear plates in ducted propellers and on rudders. This recommendation is however not given in the Report.

2. Results from questionnaire on cavitation erosion.

In Fig. 5.3, a heuristic assessment of the erosiveness of particular cavitation forms is given. Could the Committee clarify the difference between fluctuating sheet cavitation and cloud cavitation? As to my knowledge, cloud cavitation in practice is most often, if not always, caused by unsteady sheet cavitation, breaking up in clouds.

3. Guidelines to minimize cavitation erosion.

In Section 6.5, the Committee provides some guidelines, with regard to manufacture of the propeller: "A high quality propeller manufacture process is required". Could the Committee be more specific here and refer to a particular ISO class (e.g. ISO-S class)?

4. Following the presentation by the Committee and the subsequent discussions, it appears that the criteria for the risk of cavitation erosion by breaking up sheet cavitation could be classified after its mechanism. This means that we would have to study criteria for the following eventual properties:

- Occurrence of breaking up sheet cavitation,
- Energy distribution in shed sheet or cloud,
- Track of shed cavity sufficiently close to blade surface.

These questions seem relevant with respect to the reports that limited pressure side sheet cavitation does not necessarily lead to erosion.

It would assist the research labs in defining their problems and generating the necessary funding if the Committee could give a recommendation for further research in the above fashion.

2. COMMITTEE REPLIES

The Committee would like to thank all the discussers for their due diligence and interest in our work.

2.1 Reply of the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships to Colin Anderson

The Committee is grateful for Dr. Anderson's interesting and informative discussion about the use of soft protection through application of paint and for bringing our attention to the work on the propeller of the University of Newcastle's research vessel. The use of soft coating definitely has potential but more testing is still necessary to ensure damage is prevented with difficulties mainly associated with getting the correct match of coating thickness and peel strength for the specific location on the propeller or rudder.

2.2 Reply from the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships to Ian W. Dand

Dr. Dand is correct to raise a typographical error as stated in his question and the Committee concurs with his interpretation and apologises for missing this during the Report review process.

2.3 Reply from the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships to Do Ligtelijn

The contribution of Ir. Ligtelijn is particularly useful in further contributing to the second question of Prof. van Terwisga.

It is interesting also to see the comments on the potential use of composite materials in the production of large-scale propellers. This will certainly be of considerable interest through possible large savings in mass and the ability to perhaps achieve better control of section shape that may, as mentioned by the discusser, reduce the risk of erosion. There is certainly an absence of actual performance data within the public domain and further research into the use of composites for propeller production will be of considerable interest.

2.4 Reply from the 24th ITTC Specialist Committee on Cavitation Erosion on Propellers and Appendages on High Powered/High Speed Ships to Tom van Terwisga

In response to the questions of Prof. van Terwisga we would make the following comments.

1. Cavitation erosion is a strongly non-linear phenomenon involving both fluid behaviour and structural response. Scaling laws need to take into account physical size, velocity, material properties, and the characteristics of the fluid. The understanding of the appropriate scaling laws to use between model and full-scale still requires fundamental research of both the theoretical basis and from experimental observations. Table 4.7 illustrates the differences found in the literature on the effect of the exponents of the velocity on rate of pit formation and associated volume damage rate. This remark addresses the departure of the work of Fortes-Patella (1998 and 2000) and Choffat (2003) on the effect of test duration on the pit number rate. The test duration can explain this discrepancy by the fact that pit overlapping occurred on the samples. The work is still in progress. However, it seems that exponent 6 for velocity is more often used.

So now considering our actual “real world problems”: when testing at model scale, two questions are asked by maritime industry:

- is there any risk of erosion on my propeller or rudder?
- and if there is erosion, when do I need to replace them?

For the first question, the Committee Report explains the answer with the procedure detailing the appropriate methods for using paint test and high speed video.

For the second question, let us return to the last sentence of the Committee’s conclusion, which states ‘more research into the physics of cavitation structures/material interaction is required before damage rates at full-scale can be quantified’. However, while awaiting greater confidence in the appropriate velocity exponent for cavitation erosion rate, the best way to proceed is to conduct model tests at high speed and if possible at full-scale speed. That way, the discrepancy due to velocity exponents will be most strongly reduced.

To finish, the Committee agree that the quantitative cavitation erosion prediction is not yet available. However, more time is necessary to conduct further fundamental research on that field. Then it will be useful to recommend a future Committee to address the question of quantitative prediction.

2. As with any taxonomy of a continuous spectrum into discrete elements, there is a degree of fuzziness at the borders as is highlighted in the question asking for the distinction between fluctuating sheet and cloud cavitation. Although it is agreed that cloud cavitation is formed by the shedding of multiple small cavities at the trailing edge of a fluctuating sheet it can also be formed say through vortex bursting of a hub/tip cavity. The context here is taken to be the type of cavitation present where the damage occurs. So almost immediate cloud collapse close to a fluctuating sheet would be associated with fluctuating sheet as opposed to a cloud translated downstream and then collapsing near a surface.
3. For the third question with regard to the section on design guidance for a ‘high quality propeller manufacture process’ as

is mentioned in the Report these guidelines are intended to be just that, rather than a rules based approach or a fundamental physical analysis. For instance, a particular shipyard could interpret this guideline as requiring the specification of a particular ISO class for the propeller. However, this may still not give the precise shape as required by the particular propeller design. The shape could well be matched at the net of checking points but in-between shape deformations and so forth could induce problems. This is especially true on the leading edge towards the tip. Again a difficulty with a rules based approach as opposed to a checklist for guidance, is that it cannot capture all possible design cases. For example, small, fast workboats can equally impose high power density requirements but the requirements for propeller design will be quite different.

4. In response to the final comment it is evident and the Committee concurs that further research is required into the detailed physics of cloud cavitation. In particular, when it occurs on a propeller. The ability to track, predict when a sheet will break-up and where the energy is distributed are all key questions for such further research.

References.

Choffat, T., Fortes-Patella, R., Franc, J.-P. and Archeu, A., 2003, "A Procedure to Account for Overlapping in Pitting Tests", CAV 2003, Osaka, Japan.

Fortes-Patella, R.F. and Reboud, J.L., 1998a, "A New Approach to Evaluate the Cavitation Erosion Power", Journal of Fluids Engineering, Vol. 120, pp. 335-344.

Fortes-Patella, R.F. and Reboud, J.L., 1998b, "Energetical Approach and Impact Efficiency in Cavitation Erosion", CAV 1998, Grenoble, France.

Fortes-Patella, R.F., Reboud, J.L. and Archer, A., 2000, "Cavitation Damage Measurement by 3D Laser Profilometry", Journal WEAR, Vol. 246, pp. 59-67.