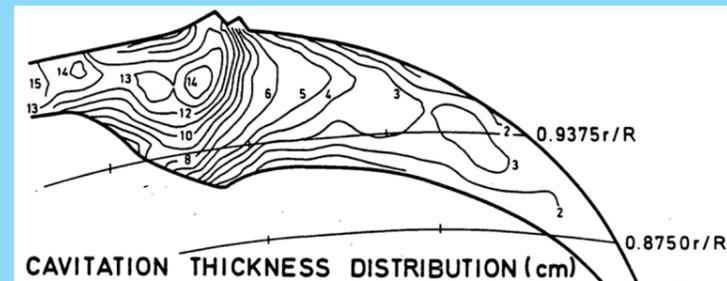
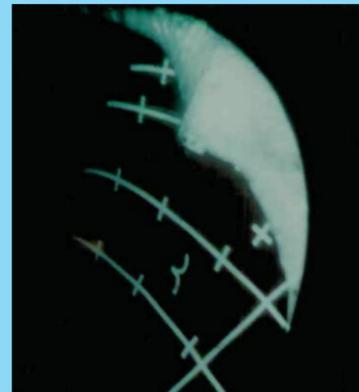


# Risk reduction by cavitation control

As all kinds of stakeholders regarding cavitation-related issues are represented in CRS, cavitation has been a major research topic through the CRS lifetime. The aim was to increase knowledge and provide members with methods to reduce risk by obtaining better control of cavitation.

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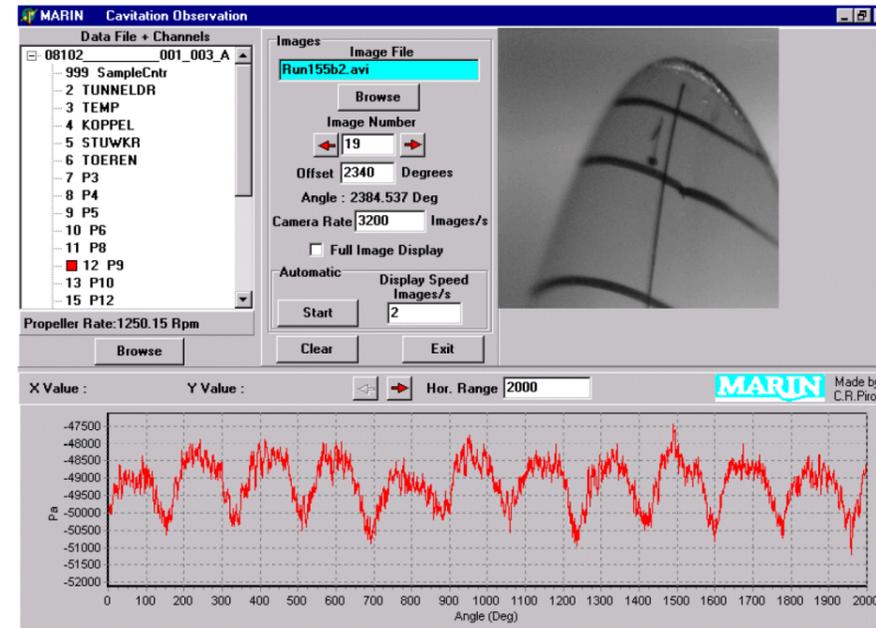
Observation of full scale cavitation by means of stereo photography (left) and the cavitation thickness distribution derived from that (right)

The early days of CRS had seen a trend of rapidly increasing power per propeller to levels beyond the experience of ship designers, operators, classification societies and propeller suppliers. With this development, cavitation became a more serious issue as it caused erosion of propeller blades, ship vibrations and noise.

Aspects of cavitation were already studied within the first CRS projects in the seventies, but from the eighties on, extensive research

focused on cavitation alone was carried out. In the first project a knowledge basis was formed. CRS members provided data from hull-pressure fluctuation measurements and cavitation observations on board ships. These included unique measurements of cavitation thickness on full-scale propellers.

Together with an assessment of the then available prediction tools within the CRS membership, the state-of-the-art knowledge on cavitation could be described and



Screenshot of CRS software application for the analysis of pressure signals due to cavitating propellers

gaps in the knowledge identified and subsequently studied. Much work was devoted to the influence of the velocity distribution in the ship's wake, as this is strongly related to cavitation dynamics, which are determining for erosion and vibration excitation issues. The sensitivity of analytical prediction methods, regarding effects of variations in propeller geometry or wake, was also studied. This was verified by experiments on model- and full-scale.

The effects of propeller manufacturing tolerances on cavitation were also investigated. It was concluded that, in order to obtain better control of cavitation for specific applications, tighter tolerances than the standard ones should be specified. In addition to unique datasets, a major deliverable of the project was a set of guidelines for the reduction of excitation forces due to cavitating propellers. This provided a practical help for ship operators, shipyards, classification societies and propeller designers, enabling them to discover potential cavitation-related issues in the early design stage, as well as how to mitigate such problems once they occurred on a ship.

## Extending on vibration excitation

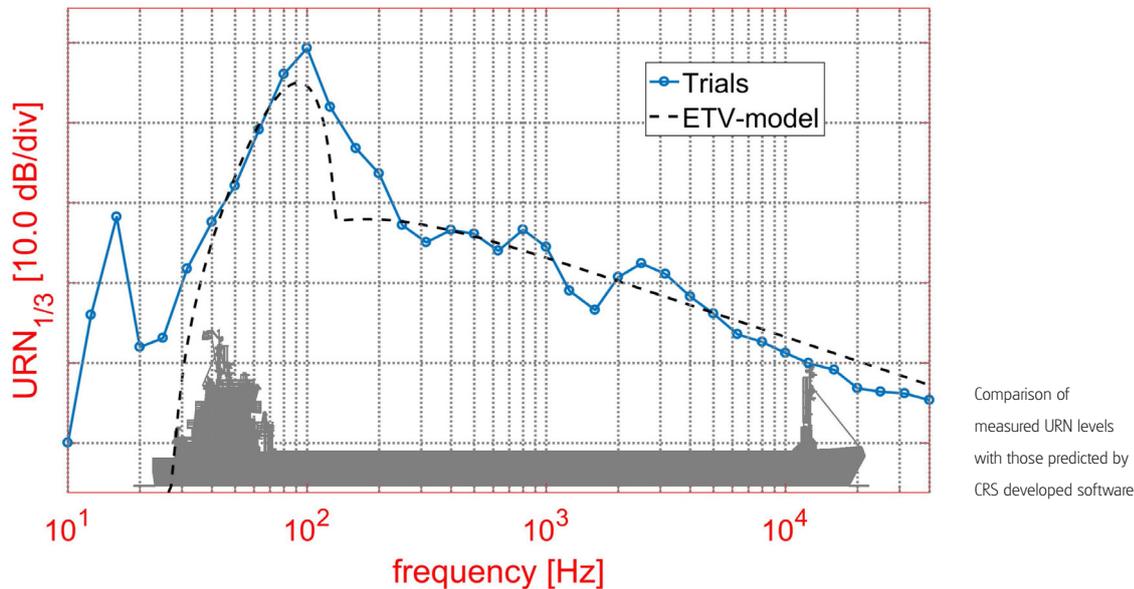
In the 1990s CRS cavitation-related research focused on cavitation-induced hull excitation, in particular at higher harmonic and broadband frequencies. The experiences of several CRS members made it clear that there was a need to develop guidance and prediction methods that could be applied at the design stage of a ship. A study of model propeller test data showed that the harmonic



Example of damage to a propeller blade due to cavitation-induced erosion

character of higher blade rate orders was intermittent, which tended to be reflected in the frequency domain as a broadband character. This suggested that the intensity and the phasing of cavitation events lay at the origin of the broadband problem. Next, a general method for decomposing a pressure signal into its continuous harmonic and impulsive components was developed and this meant that the characteristics of different cavity structures, in terms of their signal generation, could be understood. Detailed model testing and efficient software, allowing simultaneous visualisation of high-speed video images, pressure time series and corresponding pressure signals were vital here.

In the last phase of this research the knowledge gained and the tools developed were validated. A large amount of valuable ship scale data was made available by CRS members for no less than eight ships. Maximum hull pressures and source strengths computed showed reasonable results for the first blade rate component but failed to produce useful results at the higher harmonics. Further study of the excitation caused by cavitating tip vortices was therefore necessary.



**Extending on erosion** The costs of repairing erosive damage to a propeller or rudder are high, whereas fuel costs rise when propeller blades are roughened by erosion. Early in the 21st century the EU-sponsored cavitation erosion research project EROCAV was conducted. One deliverable was the “Cavitation observation handbook”, of which the importance was such that the EROCAV membership approved dissemination of it beyond the limits of its sponsoring members.

Within CRS it was considered important to investigate basic physics of hydrodynamics, material response and cathodic protection. This became possible by applying new experimental techniques. One of the CRS members developed an Acoustic Emission (AE) technique by which crack growth in materials can be related to the energy of imploding cavities and applied a sonotrode technique to test the response of different materials, material treatments and cathodic protection. Another new technique was high-speed video. The AE technique was simultaneously applied with high-speed video recordings of the cavitation to a number of rudders at full-scale. Fundamental knowledge on cavitation dynamics was increased by model-scale experiments in

a high-speed cavitation tunnel on a foil. Recordings of up to 50k frames per second were made of imploding cavities, synchronised with AE measurements. The erosion studies were concluded by issuing jointly written design guidelines for rudders and propellers, providing concrete practical guidance.

#### Broadband excitation and noise

The work done on broadband hull excitation in the 1990s was continued. In addition to the issues addressed then, Underwater Radiated Noise (URN) of merchant ships was studied because of its effect on the behaviour of marine mammals and fish. New prediction methods for broadband noise emitted by either tip vortex cavitation (ETV model) or sheet cavitation were developed, making use of results obtained by the boundary element method PROCAL that was also developed through CRS. Available empirical methods were evaluated, and the structural response of the ship by broadband excitation was investigated using finite element methods, as well as statistical energy analysis type computations. Computational models were validated using data obtained from sea trials that were sponsored by CRS. The URN was measured from a military research

vessel, a general cargo vessel and a containership. Of these latter two vessels, the hull pressure fluctuations and structural vibrations were also measured, from which the relation between hull-pressure fluctuations and URN could be investigated. The developed computational models were used in a propeller design study to evaluate efficiency, hull pressure fluctuations and URN, and became part of the CRS propeller software suite. This software suite is currently being extended with a semi-empirical method to predict the noise inboard of the vessel by cavitation.

The CRS research line on cavitation spans a period of some 35 years. Based on knowledge gained about basic aspects of cavitation and related hull-excitation, research expanded on more specific aspects, like higher harmonics, broadband hull excitation and cavitation erosion. Recent work includes URN. CRS members contributed by carrying out parts of the research and by making data and research methods available. Practical guidelines and validated prediction methods were the result, and these contribute to achieving the higher goal: the reduction of risk for the member organisations in their daily business by gaining more control of cavitation. —