MONOGRAPH PUBLISHED BY THE NETHERLANDS MARITIME INSTITUTE

# *Ship vibration state of the art 1979*

*R. Wereldsma*

**M 38**
**June 1980**

SSL 227

# *Ship vibration state of the art 1979*

*R. Wereldsma*

*En visant à des choses impossibles,*
*on obtient à la longue des choses*
*possibles, auxquelles on n'eût jamais*
*atteint autrement.*
Sainte-Beuve (1804–1869)

## PREFACE

On the initiative of the Delft University of Technology and the Netherlands Maritime Institute an investigation has been started to obtain an updated general review and state of the art of the challenging ship vibration problem. For that purpose a large number of institutions working in shipbuilding and Naval architecture has been asked to supply recent literature and information about investigations dealing with the mentioned subject. In the mids of 1979 a circular letter has been issued to almost 90 institutions asking for recent publications from the last 4 years.
An encouraging large number of reactions on this letter has been received and the author is grateful for so many contributions from all over the world. There were so many reactions in the second half of 1979 that the completion of this report, originally scheduled for December 1979, had to be delayed. A complete list of institutions is given in the acknowledgement. As a result of this endeavour this report may inform you about the complexity of the problems involved, when trying to predict the vibration performance of ships, and is intended to give a general overview, and to indicated areas where attention is necessary.
As a result of the wide variety of engineering professions involved in the ship vibration analysis, many institutions of different disciplines may have worked in this area. In this report the evaluation is restricted to available literature from institutions affiliated to the Shipbuilding and Naval-Architecture profession, and to publications not older than 4 years, however, for the sake of completeness, with exemption of some titles.
Although completeness and full coverage was the ultimate goal, it is very well possible that some information has been overlooked and references pertinent to the subject has not been processed and evaluated.

Netherlands Maritime Instiute
Research Coordination Bureau
June 1980.

CONTENTS

# SHIP VIBRATION

State of the art 1979

by

PROF. DR. IR. R. WERELDSMA

*Delft University of Technology*
*Shipstructure Laboratory*

## Introduction

For many years ship vibration problems have been studied by a wide variety of researchers. The vibration problem became urgent when economical developments required fast sea transportation with high powered ships or full ships forms with an unfavourable propeller inflow. The strong competition of the last years between the yards have resulted in cheaper and as a consequence in a relatively lighter structural realisation of plating and relevant details of the outfit. Together with the tremendous increase in ship size or special shapes of the afterbody the "vibration resistance" of the ships structure was reduced.

During the past 10 years research has been carried out on various aspects of the ship vibration analysis.

This analysis may be outlined by the following scheme:

### A. *Excitation of the hull*

The very cause of the vibrations are the time-dependent forces exerted on the hull or the appendages.

A strong hull excitation is caused by the propeller. Fluctuating forces excited by the propeller on the *shaft* excite the hull through the shaft bearings.

Fluctuating pressures caused by the finite blade number and blade cavitation are sensed by the hull surface and are a main cause of hull vibrations. Also appendages such as the rudder and the propeller shroud (if applied) are sensing the vibratory pressure of the propeller and convert these pressures into *hull excitation forces*.

Also the blades of the propeller itself are subject of a vibration analysis.

Another cause of hull vibrations may be found in various types of *wave excitations*. Short high frequency waves may ring the ship in its fundamental mode of vibration. Other phenomena are more combined with ship motions and waves and do excite the hull by slamming or whipping.

Excitations can also be generated by the *prime mover* in the case of reciprocating engines. The hull is than excited by the fluctuating foundation forces.

### B. *Response of the hull and accessories*

The hull, being a complex structure operating in water, will convert the excitation, mentioned in the preceding paragraph, into a *vibratory displacement* of the overall hull (global response), of details of the structure (panels, pipes, deckhouse, double bottom, bridge wings etc.) (regional response), and small details such as furniture, instruments, tables, masts etc. (local response). All these types of the vibratory motions belong to the response of the hull and are due to the mass-elastic properties of the structure.

Also vibratory material-stresses or -loadings may be the result of the hull response analysis and although the vibratory motions may be acceptable, the structural integrity may be in danger because of *fatigue problems* (e.g. thrustbearing-foundation, prime mover foundations, propeller-shroud support etc.).

Effects of the water-environment such as added mass, damping and buoyancy are the subject of hydrodynamic studies and do complicate the entire analysis.

Methods of analysis are based on the mass-elasticity properties and can be handled by rational mechanics. Analytical methods as well as numerical methods (F.E.M.) are in use to calculate the response.

### C. *Criteria for design and acceptability of the vibrations*

Finally efforts have to be made to arrive at practical criteria for design and acceptability of the vibration level. Since acceptability criteria based on the habitability of crew and passengers are now being discussed internationally and may result in *standards* of acceptance, it makes sense to adapt and improve the *design criteria* and the *"intermediate" criteria* to the available final standards of acceptance. Since habitability of crew and passengers is related to human reactions and is independent of the technicalities of the ship, it is not only necessary to *analyse* the vibrational behaviour of the ship, but also to *influence* the vibration level by design and structure modification in order to meet the internationally adopted requirements and standards.

It must be stated that the *personnel* aboard the ship

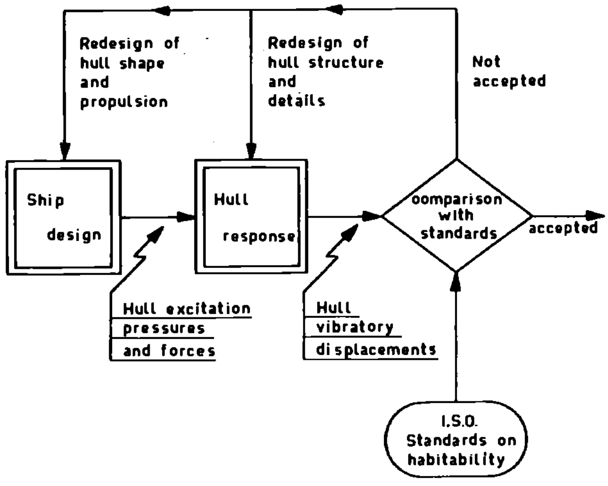


Fig. 1. Three steps of ship vibration evaluation.

are *small* and local "systems" *itself* and are highly sensible for local vibrations. Therefor the final judgement of the vibratory behaviour of the ship for habitability will be based on the local vibrations more than on the overall vibrations and it is this vibration level that is important to evaluate and to control.

The scheme of Fig. 1 illustrates the three steps to be distinguished.

For a guidance of the ship designer in order to have an early impression about the acceptability at the final judgement of the entire ship, various intermediate criteria have been developed. Criteria on ship lines, wake quality, and propeller design are now in progress. Also criteria for acceptable hull pressures and forces can be found in literature. Although these criteria may be helpfull for the ship designer to evaluate his design in an early stage, nothing can be said about the vibratory displacements of regional and local structures, being so important for the acceptability. A favourable low excitation-level, combined with an unfavourable structural response may result in a unacceptable vibration level.

In Fig. 2 various design criteria have been indicated. A criterion on hull response is not available and development thereof is strongly recommended.

In this state of the art report all the subjects mentioned in the introduction have been touched by the evaluation of recent literature.

The various subjects will be considered in the same sequence as given in the introduction. Most of the work is devoted to the hydrodynamic propeller excitation and the structural response. The available literature has been catagorised according to Table 1, where a similar subdivision has been made as for this report itself. References are numbered in a two-number code. The first number refer to the chapter of application.

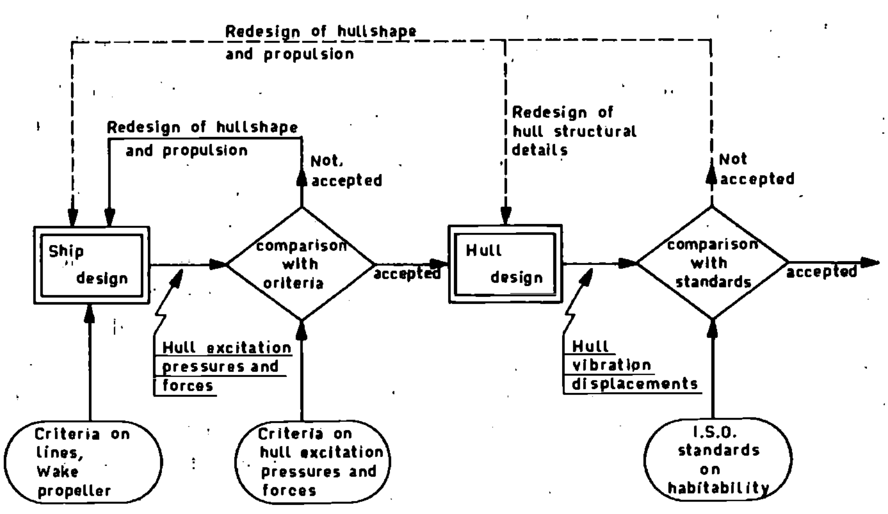


Fig. 2. Existing design criteria for ship vibration.

Table 1. Categorisation of literature (352 titles)

**Chapter 1 Excitation** (93 titles)

*Section 1.1, par. 1.1.1*
on hull shape and wake
on the medium
on cavitation, pressure field etc.
on full scale pressures
general

*Section 1.1, par. 1.1.2*
on propeller blade and shaft forces
experimental
theoretical
miscellaneous

*Section 1.1, par. 1.1.3*
on wake criteria
on pressure criteria
general

*Section 1.2*
on wave induced vibrations

*Section 1.3*
on prime movers

**Chapter 2 Response** (193 titles)

*Section 2.2*
on hydrodynamic effects
on global response

*Section 2.3*
on regional response
on shaft response

*Section 2.4*
on local response

**Chapter 3 Criteria** (14 titles)
on criteria
on standard

**Chapter 4 Miscellaneous** (52 titles)

*Section 4.1*
on damping, isolation and acoustics

*Section 4.2*
on statistical methods

*Section 4.3*
full coverage
non specific

# 1 Excitation

## 1.1 *Propeller excitation*

The *propeller* of the ship, being the very cause of the observed vibrations of importance for habitability and acceptability, will be dealt with in detail in this report, in particular in connection with the wake, the afterbody, the cavitation and the shaft.

Generally two types of propeller generated excitations can be distinguished i.e. the "hull forces" and the "shaft forces".

The scheme of Fig. 3 is applicable for the parameters involved.

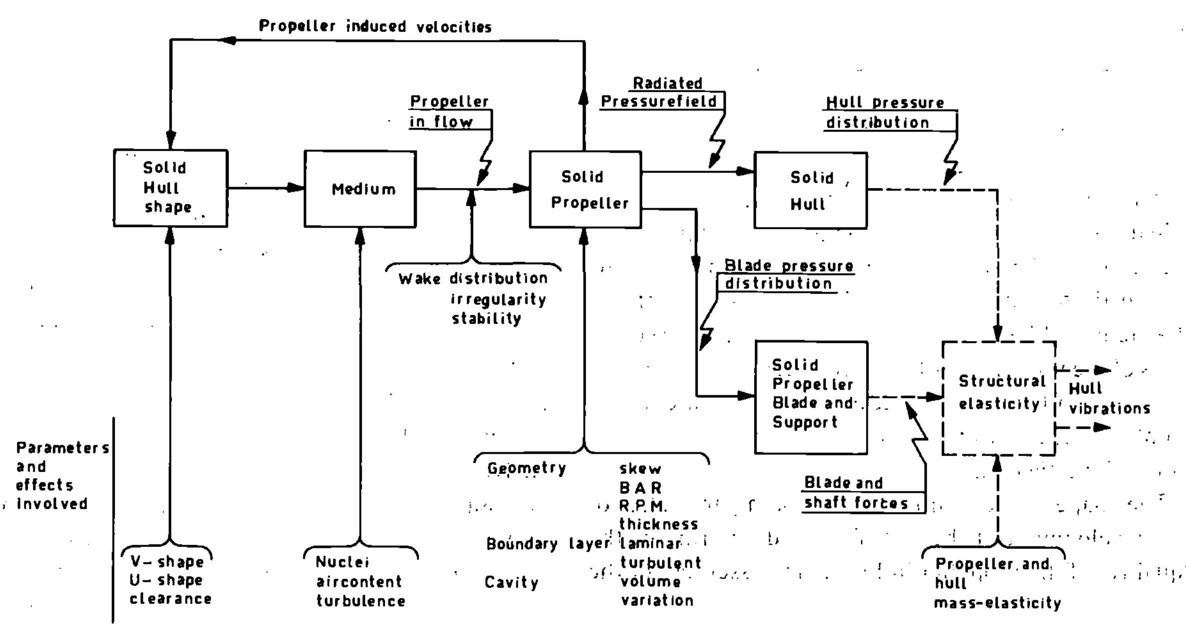


Fig. 3. Scheme of parameters for propeller excitation.

### 1.1.1 Determination of "Hull Forces" [1.08–1.27]*

#### 1.1.1.1 Experimental

From the scheme of Fig. 3 it may be observed that a wide variety of physical parameters is involved in the determination of the "excitation". It also may be concluded that a strong interrelation exists in the excitation and response of the hull, and a careful interpretation of the results of investigations has to be made. In particular when experiments on model or on full scale are carried out,this interrelation can hardly be avoided. Since *cavitation* generates the most important portion of the hull excitation, much research is devoted to this subject as well by experiments as by theory.

For the experimental investigation *fundamental* cavitation research can be carried out either in a regular cavitation tunnel or in a depressurized test facility including a scaled or distorted model. For *practical* experiments leading to hull excitation levels the presence of a model is a necessity and depressurized test facilities such as a circulating water channel, a vacuum towing tank, a large cavitation tunnel with a distorted model, need to be available in order to take the propeller-hull interaction into consideration.

In order to stabilize the time dependent cavitation phenomena, being essential for the radiated pressure, the *nuclei and aircontent* (as well as its distribution in bubble size and density) of the propeller inflow is now a subject of intensive research, also reported in the ITTC propeller and cavitation committee reports [1.06, 1.07, 1.68].

This physical condition in the test facility, apart from the other longer known parameters such as blade loading and $\sigma$-number, has a dramatic influence on the development of propeller cavitation and is of importance because the water in the facility tends to change slowly its air- and nuclei-content in the long run.

The *wake* in which the propeller operates is another difficult subject to deal with [1.01–1.05].

An important step forward in the experimental determination of the flow distribution is the development of the laser doppler anemometer, now being in use at several institutes and also applied on full scale. This instrument enables us to measure the mean inflow conditions of the propeller with the propeller in operation, so that an important effect of the propeller-hull interaction problem, i.e. the propeller induction on the wakefield, can be investigated.

The shape of the hull is still the main parameter for the development of the wakefield and determines the "quality" of the propeller inflow, being essential for the development of cavitation and pressure fluctuations.

In the experiments the wake suffers from *scale effect*. A continuing story on wake-scale effect studies can be found in the literature, this because of the fundamental impossibility to have equal Froude and Reynolds numbers for models being smaller in size than the full size ship. Efforts are made to correct the wake distribution, as observed on models, to full scale distributions, apart from the propeller-hull interaction, by considering the viscosity of the medium (boundary layer suction, distorted models).

The *propeller* operating in the wake behind the hull will transfer the unequal inflow in fluctuating blade loadings and cavitation. Stability of the time varying cavity is influenced by the steadiness of the wake, the nuclei content and the boundary layer stability on the blade.

The time variation of the size of the cavity, its growth and collapse is the main cause of the fluctuating pressures. Besides that, blade thickness and the blade loading and its variations do contribute to the radiated pressure field.

For a *solid* boundary nearby the propeller the pressure field will generate a pressure distribution on the boundary surface, being the very hull excitation, of importance for the vibrational behaviour of the ship.

Experimental techniques, developed in order to determine the hull pressures, need to be applied in a facility where cavitation can be obtained (depressurized facility) and a *solid* hull can be inserted (sufficiently large size of the test section). In many cases the solidity of the hull (boundary) is doubtful and interpretation of the results of these measurements requires much care.

Open questions are:

1. How far away on the hull is still "nearby" the propeller, in other words, how much of the *solid hull* surface needs to be included in these experiments. The propeller committee report of the 15th ITTC (1978, The Hague) indicated that 1/4 or 1/3 of the hull forward of the propeller is still of importance.
2. How solid is the hull on which the measurements taken place and what is the effect of an elastic vibratory reaction of the model, in particular when compared with the areas having smaller pressure amplitudes.

Integration of the pressure distribution on the hull depends on the way the vibratory reaction of the hull is analyzed. Following the "Normal Mode Analysis", it is necessary, before integrating the pressure over the surface, to multiply the recorded pressures with the shape of the modes in which the hull can perform "free vibrations" (see also Chapter 2, Response, Generalized Forces).

For other types of analysis (e.g. a direct Finite Element Calculation) the integrated hull pressures are only

* Numbers in square brackets refer to the list of references.

of restricted value.

The very excitation input for a dynamic hull analysis requires a distributed pressure or an approximate discretized version of that, i.e. forces on the grid points of the discretized model obtained by pressure integration (Finite Element breakdown). The pressure fluctuation on a single point has no value for a vibration analysis.

One of the main problems in the experimental determination of the fluctuating hull pressures is the scale effect. Also the importance of the scale effect on the prediction of the final vibration level is not firmly known.

The main course of the pressure fluctuations is the rate of change of the cavity volume. To have this phenomena properly scaled, the classical problem of wake scaling is involved. The *mean value* of the wake can be corrected for by adaptation of the model speed, but the *distribution* of the wake velocity in the propeller plane is still a problem to be solved. Boundary layer suction and distorted models are well known methods but application has not proofed to be successful. The error of the scaling problem is estimated to be 50%, which is a rather large figure when sensed in an absolute manner. For the predictions of a *vibration level*, however, the error in the results of the experiments may be acceptable because human sensibility is measured in factors instead of percentages (dB scaling).

#### 1.1.1.2 Theoretical methods [1.28–1.35]

The theoretical developments concerning hull excitation can be treated according to the same lines as given in Fig. 3.

The following steps can be distinguished.

- Analysis of the flow around the hull and the effect of the propeller on this flow, which is the very input for the analysis of the propeller performance (lifting-surface theory).

In connection with the complexity of the analysis of flow lines around the hull only scarcely a publication can be mentioned treating the problem of the hull wake calculation.

- The liftingsurface theory, to convert the propeller inflow and the propeller rotation into blade pressure the distributions is well developed and results are satisfactorily verified with experiments.
- For the calculation of the time dependent cavity volume a strip wise quasisteady approach is applied. For this analysis improvements are required and the theory is still under development.
- The theoretical conversion of the time dependent cavity volume to radiated pressures in the medium and on solid boundaries can be estimated as well developed.

Comparisons with experimental results show, in the context of vibration analysis, reasonable results, although solid boundaries in the experiment and wake input in the theory are doubtful parameters. It seems that, for the time being, the wake, being the input of the propeller-calculations, is still to be determined experimentally (see par. 1.1.1.1). More promising results can be reported for the analysis of the dynamic propeller performance i.e. cavitation, instantaneous pressure distribution, radiated pressure field and hull pressure.

Comparisons of calculated results with experimental results are of such a quality that the conclusion to improve theory or experiment is of equal probability.

#### 1.1.1.3 Evaluation

Generally speaking it can be stated that the experimental and theoretical research in the propeller pressure field tends to go towards more fundamental research in flow phenomena. Also research is observed in the propeller performance for non-stationary conditions (manoeuvres, seakeeping and propeller backing). Theoretical developments are in progress to predict the instationary cavitating performance and its effect on the pressure radiation. Seen from a point of view of the vibration analist, interest is focussed on the steady state vibratory operation and the design stage prediction of the hull excitation (by theoretical and/or experimental means). A relatively rough information of the fluctuating pressure distribution may suffice for an appropriate analysis of the vibration level, because the required accuracy is related to the human sensitivity for vibrations and to the relatively rough levels of acceptance (decibel scaling).

### 1.1.2 Determination of shaft forces

#### 1.1.2.1 Experimental [1.43–1.55]

Generally the experimental determination of propeller shaft forces is carried out in a regular towing tank behind a ship model. More advanced methods make use of depressurized facilities such as a vacuum towing tank and circulating water channels.

Since the wake, in which the propeller with finite blade number operates, is the very cause of the vibratory propeller operation, an accurate wake reproduction is a necessity. For that reason cavitation tunnels operating with a model measured wake reproduction (flow regulator, screens) are only valuable when fundamental studies are undertaken. For practical application, i.e. to determine the vibratory shaft forces of a real ship, the wake reproductions have to be considered as to be too inaccurate.

Also for measurements behind models the scale effect of the wake is still a matter of great concern and no firm solutions have been found for the resulting inaccuracy.

Experiments in depressurized facilities, enabling the propeller to develop cavitation during the vibratory force measurements have indicated that, with minor exceptions no serious effects of cavitation on the vibratory propeller forces exist, so that the cavitation phenomenon is of minor importance for this subject.

The instrumentation necessary for this type of measurements must be carefully designed from a point of view of dynamic response. This response problem is similar to that of the hull pressure measurements, although for the latter case the problem has not been recognized so clearly.

Recently the experimental possibilities have been extended to other interesting quantities such as blade spindel torque, single blade forces and blade stresses for controllable pitch propellers and blade strength analysis respectively.

In regular cases the propeller elasticity is so small (natural frequency high) that blade bending needs not to be concerned. For extreme cases, such as highly skewed propellers with large blade area ratio, it might become important [1.49, 1.64].

Close to the propeller shaft forces, exciting the hull through the shafting, are the vibratory forces generated in the support of the various appendages nearby the propeller, such as shroud and rudder, equally exciting the hull, and of similar importance as the propeller itself. Little has been reported in the literature about these subjects.

#### 1.1.2.2 Theoretical determination of vibratory shaft forces [1.56–1.62]

Apart from the wake input to the propeller, the analysis of the fluctuating blade loading, blade forces and shaft forces can be judged as well developed. The instationary lifting surface theory, developed and available at various institutes (NSMB, Davidson Lab., MIT, NSRDC) gives reliable answers. The weak point, however, is still the determination of the distribution of the propeller inflow as discussed in section 1.1.1.1.

Efforts are being paid to simplify the analysis, because the lifting surface theory is relatively expensive. Fast development of computer facilities however may change this statement in the future. Quasi-steady, two-dimensional unsteady, and the unsteady lifting line approach, together with correction factors for the three-dimensionality are still in use. If however cavitation phenomena, blade stress analysis and spindle torque are to be analyzed, the lifting surface theory is the appropriate tool.

#### 1.1.2.3 Evaluation

From the viewpoint of the vibration analist it can be stated that, apart from the scale-effected wake, the theoretical and experimental methods to determine the various time dependent forces of the propeller are well developed. Design stage prediction techniques of the vibratory operation of the propeller start with a reasonable accurate knowledge of the propellershaft forces, being the input of the shaft vibration analysis.

### 1.1.3 Criteria for wake quality and acceptability of propeller excitation [1.65–1.74]

Because nowadays the maximum ship vibration level becomes part of the contract between the shipbuilder and the shipowner (see also Introduction), the shipbuilder wants to know in an early design stage whether or not his ship-design may suffer from severe vibrations. For that purpose criteria on the wake quality, the output of a single pressure pickup (during a model measurement), the integrated hull surface force and the dynamic propeller shaft forces have been developed, based on experience with other ships or model tests. Wake criteria are reported in [1.65, 1.66] these criteria not only serve the vibration problem, but implicitely also the problem of severe cavitation on the propeller.

Generally speaking these criteria are only an *indication* about a *possible* vibrational behaviour (favourable or unfavourable).

When the design of the ship proceeds, firm information becomes available and an accompanying proceeding process for the vibration analysis needs to be available for proper design guidance. In this respect the mentioned series of criteria for the excitation needs to be extended to the next step i.e. the response, so that the final vibrational analysis results in reliable answers about the vibration level of the real ship in operation.

## 1.2 *Wave excitation*

### 1.2.1 Springing [1.75–1.83]

Another source that may introduce a serious type of vibration in the lower modes is the critical 2-noded vertical hull resonance generated by short incoming waves having a frequency of encounter coinciding with that of the 2-noded vibration. This phenomenon is named *"springing"* and becomes relevant for large ships (low natural frequency) having relatively high speeds (high frequency of encounter). For non-extreme ship size and speed both frequencies were sufficiently apart to avoid the critical situation, but nowadays a coincidence of natural frequency and frequency of encounter (excitation frequency) may well occur. The phenomenon is well understood but still research is going on for the determination of the vibratory wave loading caused by relatively short waves.

Specially designed experiments and developed theories have been published recently [1.80]. It can be concluded that the well developed theories for the analysis of ship motions, based on strip theory (two-dimensional approach) for the calculation of the wave forces must be modified in order to take care of the three-dimensionality for the short waves and shorter nodal distance of ship deflections. Also non-linearities in the conversion from wave elevation to pressure fluctuations and hull excitation may result in a critical excitation [1.83].

### 1.2.2 Whipping and slamming [1.84–1.91]

*Whipping* and *slamming* are phenomena belonging also to this section. This type of excitation differs from that of springing but both are wave generated phenomena, known for a much longer time than springing. Slamming is to be distincted from whipping and springing by the frequency content of the excitation. As the word already suggest in the slamming phenomenon impulsive excitations plays a role and as a reaction the hull will ring in a series of fundamental modes, all excited simulaneously and causing a high displacement and stresslevel right after the impact. For springing and whipping the excitation contents only the frequency of the first elastic mode (2-noded vibration) and will ring the ship only in that mode. Much effort has been paid to analyze whipping and slamming excitation based on probabilistic approaches.

As a logical extrapolation it might be worthwhile to consider also the critical excitation in the torsional mode of open fast container ships. Due to the open hull of the container ship the first torsional-horizontal mode may have a very low frequency that might coincide with the encounter frequency of oblique short waves generating a similar phenomenon as springing but then for the torsional mode. Again in connection with the subject of this chapter the determination of the oblique wave excitation, experimentally as well as theoretically, is still in a stage of development [1.76].

### 1.2.3 Evaluation

The phenomena of springing, whipping and slamming are to be distinguished by the frequency content of the excitation, springing being more or less mono frequent (coinciding with the 2-noded vibration frequency), whipping narrow banded (with frequencies in the range of the 2-noded critical frequency) and slamming impulsive i.e. broad banded (generating transient vibration of the hull in many nodes). The response side of the problem is well understood. Determination of the excitation in particular for short high frequency waves requires much attention, because the three-dimensionality of the problem plays an important role (strip theory fails for shorter waves).

Although the subject of wave excitation of the 2-noded hull vibration mode may not be a serious subject for the habitability of the passengers and crew (ship operators can avoid this type of vibration, without doing too much harm to the transportation efficiency) it is a subject of great concern for material specialists, because a serious 2-node vibration may influence the fatigue-resistance and lifetime of the hull structure. In this respect attention is paid to the probability of occurrence and the level of expected material stresses, to be superimposed on the regular wave generated stresses. Research on these phenomena is still going on.

### 1.3 *Engine excitation*

For the case the prime mover and also other machinery have unbalance-forces and explosion reaction forces, these forces will excite the ship structure, and can be seen as excitation forces. The analysis of these forces can be carried out by rigid body mechanics. More problems are encountered when the response needs to be analyzed, being the subject of the next chapter. Recent work can be found in ref. [1.92, 1.93].

## 2 Response

### 2.1 *Subdivision of the response analysis*

The response problem of the ship's hull and its installations can be subdivided into several areas and regions.

A. For the vibratory response various regions are distinguished i.e.:
   1. *Global* response of the hull. The overall reaction of the entire hull on various excitations.
   2. The *regional* response of restricted areas such as engine room, superstructure, afterbody, bridge wing.
   3. Special *regional* systems such as prime mover, propeller shaft, propeller, in axial and lateral direction.
   4. The *local* response of details of the ship such as stiffened panels, beams, appendages, cabin floors, tables, furniture, etc.

B. The *response characteristics* are governed for a great portion by the *mass-elastic analysis* of the structure (e.g. in the "dry" areas, deckhouse), but also partly by a *hydro-mass-elastic* analysis of structural parts such as the hull (added mass, damping), the propeller (hydrodynamic propeller coefficients), double bottom, shloshing of fluid in holds, etc.

C. For a great deal the analysis of the vibratory response is based on a deterministic approach, working with time invariant harmonic excitation forces. In some cases a statistical analysis (spectral analysis) is applied to describe the vibratory output. In particular for r.p.m.-fluctuations of the propeller, or for interfering twin screw excitation the latter type of analysis is of advantage.

A vibration analysis of local systems may be complicated by the overall deformation of the hull due to wave loading. The natural frequencies of local details such as panels may be effected by the overall stress condition of the detail under consideration (approaching the buckling load for a panel means a shift of the natural frequency towards zero). For a propellershaft being misaligned by the bending of the hullgirder the dynamic properties of the bearings may influence the natural whirling frequencies.

For the time dependent hull deformation these effects give rise to time dependent dynamic properties of structural details causing a time dependent modulation of the vibratory output and a spectral analysis becomes a requirement.

## 2.2 *Global hull response*

### 2.2.1 Hydrodynamical [2.01–2.32]

#### 2.2.1.1 Theoretical

Problems are to be reported when the effect of the medium has to be taken into account. The determination of added mass and damping of the medium is still subject of investigations.

For the lower modes analytical procedures are still reported in literature but for complex higher modes finite element techniques are being developed [2.28], the "Fluid Finite Element Method". Recently infinite fluid elements have been introduced [2.23] resulting in a reduction of the required computer time.

The damping of the structure is still a subject of research. Damping coefficients observed at full size experiments are up till now not predicted theoretically and even not approached by theoretical means [2.97].

The damping introduced by the fluid does not explain the full size observed values and are even not represented in the Fluid Finite Element Approach. For that reason an artificial damping deduced from experience is introduced in the set of equations.

The solution results in natural vibration shapes and natural frequencies, and for the case a forcing vector is introduced, an output of the vibratory displacement of the nodal points is generated. From these displacements an estimate can be made of the vibration level aboard the ship.

#### 2.2.1.2 Experimental

For the experimental determination of the hydrodynamic effects of the global hull vibrations not very much activities during the last years can be reported. The application of the Normal Mode Method makes a rational experimental technique applicable. As an extention of the techniques applied in shipmotion research (where oscillation-tests are applied to determine the hydrodynamic coefficients) segmented oscillator experiments are proposed. The hull will be forced in a modal displacement (in an approximate manner) and hydrodynamic reaction forces are measured in order to determine added mass and damping coefficients.

### 2.2.2 Structural [2.33–2.126]

The method of analysis to be applied for response calculations is strongly dependent on the excitation fre-

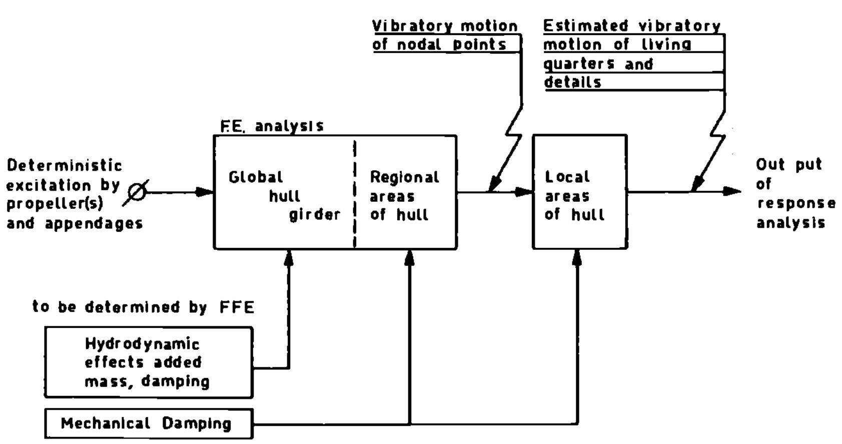


Fig. 4. Regular analysis of hull vibrations by direct methode with F.E. technique.

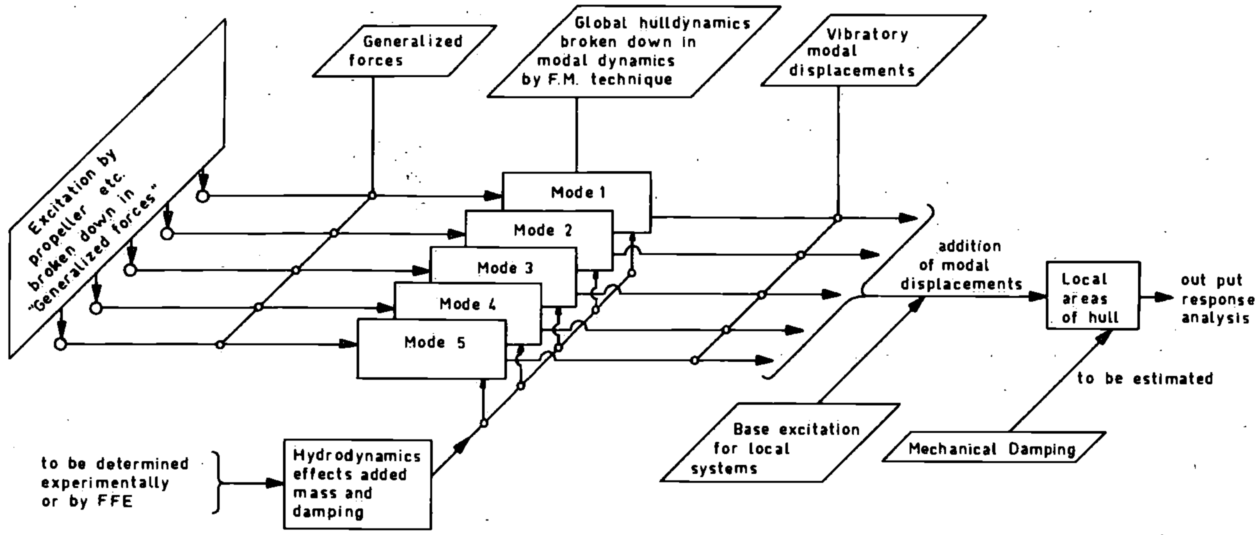


Fig. 5. Analysis of hull vibrations with F.E. technique and normal mode methode.

quencies.

For high frequency wave excitation (having frequencies low compared to those of propeller excitation) a "beam" analysis may be of sufficient accuracy (lower mode analysis).

For propeller excited vibrations a more detailed calculation model of the structure is a necessity and the application of finite element techniques became obvious. Computer programmes such as ASKA, STRUDL, NASTRAN are now in operational use in many research institutes (see Fig. 4).

Although the modellisation of the structure to be investigated is still subject for discussion, generally speaking the method is well developed and the mass-elastic characteristics of the structure are well determined.

A further development of this more or less global F.E.-Analysis can be reported. The *"Normal Mode Method"* (N.M.M.), although not different in essence when compared to the regular discretized (dynamic) Finite Element Analysis, (a coordinate transformation from regular "F.E.-coordinates" to "natural coordinates" as obtained from the solution of eigen value problem, determines the bridge between the F.E.M. and the N.M.M.) may result in a better physical insight in and understanding of the phenomena under consideration such as whipping and springing and, as a further development, in afterbody vibrations and interpretation of propeller generated vibratory hull pressures (see Fig. 5). For a global strength and vibration analysis, this method enables us to apply spectral signal- and system-analysis [2.82].

There is in general a problem, when interpretations are made for the local systems. Although the mesh of elements is relatively fine, a reliable prediction of the vibration level in the living quarters or in general of the *local systems*, as mentioned in the introduction, is still not well possible. An extension of the F.E. mesh to even more details leads to an impractical, time consuming and expensive operation, nowadays not accepted as a practical solution.

Gradually increasing the node-density of the F.E.-model by ***substructure techniques*** and reversily dealing with the total structure by composition of the condensed substructures may lead to an answer of the mentioned difficulty. *"Component Mode Synthesis"* techniques, as developed in aero- and space-dynamics, are now being considered for the ship vibration analysis problem [2.33].

Another approach needs to be mentioned, also developed in space craft dynamics named *"Statistical Energy Analysis"* (S.E.A.), where vibration-energy-transfer from system to system is dealt with in a statistical manner. The first applications are reported in ref. [4.28].

## 2.3 *Regional response analysis*

### 2.3.1 Regional hull areas [2.127–2.136]

Critical areas such as living quarters and working spaces (engine room, deckhouse, bridge) are subject for a detailed analysis in order to be sure to meet the requirements in the contract. Attention is focussed on a smaller part of the ship enabling to consider more details. Most of the literature deals with deckhouses and engine rooms and gives an analysis of the observed vibration level *after the ship has been built.* Prediction of the vibration in the engine room and improvements in the layout to reduce the vibration level are still subjects to be developed.

A similar statement can be made for the vibration analysis of deckhouses although, because of the fact that vibratory behaviour of the deckhouse area is of utmost importance for the acceptation of the ship by the owner, a prediction of the vibration level is often made before the ship has been delivered.

### 2.3.2 Prime mover-shafting-propeller [2.137–2.173]

In many studies this system is dealt with in connection with engine room vibration analysis because of the strong interaction between the two regions. For the analysis of the shafting and propeller it is necessary to recognize all physical parameters of importance such as the hydrodynamic propeller coefficients, added mass, damping, lateral coefficients, the elasticity of the shaft, the hydraulic coefficients of the bearings and the elastic supports of the bearings. A substantial influence can be expected from the overall bending of the hull that will effect the alignment condition of the shafting and will change the oilfilm properties of the bearings because of their dependence of the mean loading of the bearing. For the case of a diesel engine a vibratory torque and lateral bending may be exerted on the system. A full vibration analysis of the system may suffer from a number of inaccuracies. For that reason an isolated shaft-propeller-system is now subject of more fundamental investigations to focuss attention on the misalignment and its effect on the bearing coefficients [2.149]. Much of the reported work concerns measurements on full size ships, an accompanying analysis for the explanation of the measured results, the obtained solution in case practical problems had to be solved. Straight-forward prediction techniques and comparisons with full scale measurements on shaft vibrations are seldom reported, and are still under development.

### 2.4 *Local response analysis* (see also par. 2.2.2) [2.174–2.193]

This paragraph reports the possibilities to analyze local structures such as stiffened *panels, beams, cabinfloors* etc.

Analytical or discretized methods are available to calculate the natural frequencies and deflection shapes. Coincidence of these frequencies with blade frequencies and multiples needs to be avoided. The assumed boundary conditions of the details under study (support of the stiffened plates, the cabin bottom etc.) are in many cases doubtful, because the adjacent structure has not been considered in the modelling of the detail. So a careful application of the results is a necessity.

In practical shipbuilding design-stage-local-response-prediction is not well possible because not very much is known in the design stage of the local details. Therefore an approximate analysis as reported in the literature in order to avoid unwanted effects may suffice.

More over local vibration problems can relative easily be cured after the trial trip by inserting proper stiffenings and extra supports in contrast to the regional and global vibration problems that hardly can be influenced, without making an expensive redesign and reconstruction.

A special local system is the *rudder.* Only a single publication on the dynamic behaviour of the rudder can be reported. In connection with high powered propellers it can be expected that the vibratory pressures exerted by the propeller on the rudder may have substantial values to be incorporated in the vibration analysis of the hull. No attempts in this respect can be reported. A similar statement can be made for other types of appendages such as propeller *shrouds.*

## 3 Criteria and standards

### 3.1 *Criteria for shipboard vibrations* [3.01–3.13]

In the design process of a ship several criteria have been used to check the design against an acceptable vibration level. In this respect a complete range of checkpoints of increasing sophistication is in use in order to guide the ship designer when his design proceeds towards the end stage (see Fig. 6).

In the ship-design-stage efforts are paid to have the propeller inflow, the propeller geometry, the afterbody lines and screw aperture favourably designed. Vibratory hull pressures and shaft forces need to be determined either by calculations or by experiments in order to have a comparison with early stage criteria such as pressure-fluctuation-criteria formulated in ITTC 1978 Propeller Committee report, or with figures experienced with existing ships. Further an analysis of the ship structure belongs to the available tools to arrive at a vibration level of characteristic points of the ship, although in many cases, the applicability of this tool exists only when the ship is already under construction and not very much can be modified anymore.

The final answer will be given on the trial trip when the true vibration level can be observed and checked against the maximum level agreed upon in the contract between shipowner and shipbuilder.

### 3.2 *Standard for shipboard vibration* [3.14]

In order to have international agreement about the acceptable vibration level aboard ship the I.S.O. initiated years ago a discussion on a standard to be issued for international agreement, being a guideline for shipbuilders and owners on the acceptable vibration level.

This level has been subject of a long discussion in

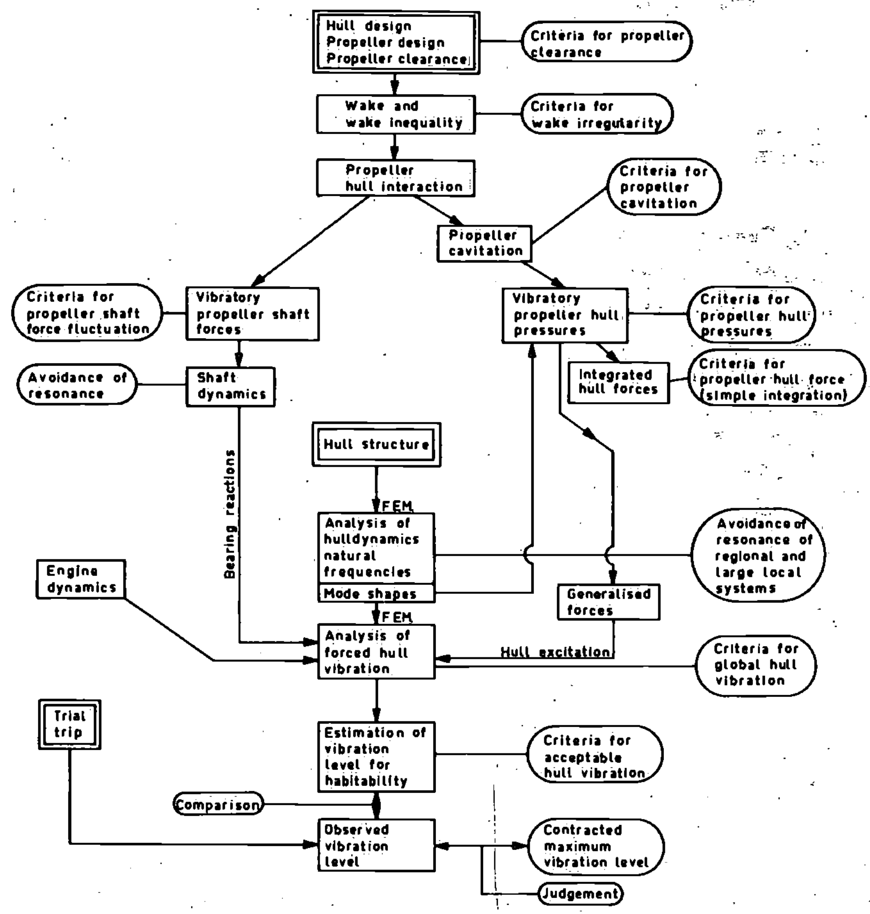


Fig. 6. Review of criteria for ship vibration analysis.

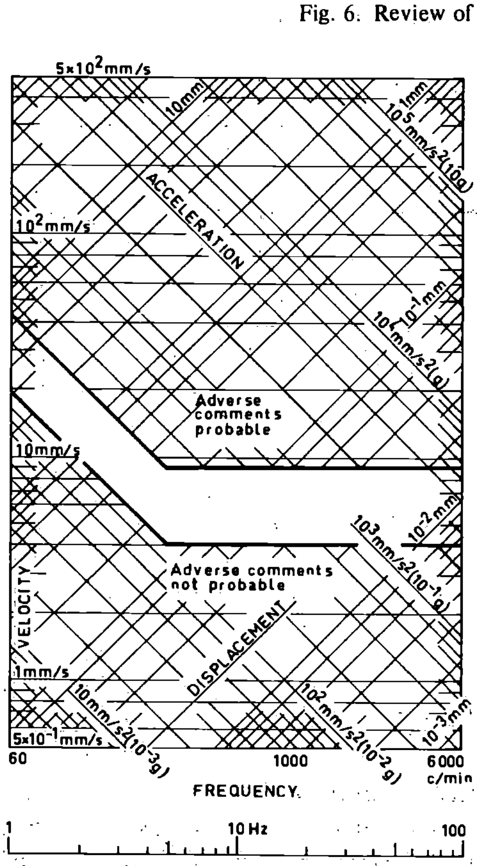


Fig. 7. I.S.O. guide lines for maximum hull vibrations for ships longer than 100 metres [3.14].
(amplitudes of half peak-to-peak values)

I.S.O.-committees and as a result a final draft proposal on vibration levels is now being issued for international agreement. These levels indicate the probability of adverse comments to be expected by the crew during operational conditions of the ship and are based on a thorough study carried out in the U.S.A., which is reported in ref. [3.01].

Typical figures are given in Fig. 7 of this report. Similarly a proposal for acceptable noise levels in different cabins and areas has been developed in East European countries and has been reported in ref. [4.18]. Typical figures can be read from Table 2.

Table 2. Proposal for maximum noise levels in various ship quarters (abbreviated, from ref. [4.18].

| Type of ship area | Acceptable noise level dB(A) |
|---|---|
| Living quarters | |
| Deck No. 2 | 68 |
| Restaurants | 65 |
| Living quarters | |
| Deck No. 3 and higher | 60 |
| Hospital | 55 |
| Workshops | 85 |
| Operational | |
| areas in engine room | 75 |
| Auxiliary rooms | 70 |
| Cook's galley | 75 |
| Communication area's | 60 |

# 4 Miscellaneous

## 4.1 *Vibration damping, isolation and acoustics* [4.01–4.22]

Active vibration dampers (and compensators) are sometimes applied to reduce the vibration level. Unbalance forces of reciprocating engines are compensated by synchronized out-of-balance-rotary exciters, for the case more simple measures are not effective.

Tuned dampers for 2-noded ship vibrations have been analyzed. It can be concluded that on the subject of tuned vibration dampers not much literature is available, and this type of damper is seldom applied.

As a sideline of the subject of this report the acoustic research in the ships environment will be reported, because the subject is closely related to vibration. In particular the human sensitivity for vibrations is strongly influenced by the noise in the environment. Also cavitation and its inception is accompanied by noise generation and helps to improve cavitation research being so important for vibrations.

Reduction of noise aboard ships is essential for the habitability, and important for the ship designer.

Vibration and noise research do have many things in common, in particular, when there is a coincidence in the frequency range of interest, e.g. for the second harmonic blade frequency components and the low-frequency noise.

The deterministic approach of the vibration analist works well in the low frequency range (lower than 10 c.p.s.), but is sometimes troublesome for local vibration levels of two and three times blade frequency, and approaches the frequency range of acoustics. Experimental techniques applied in the field of acoustic may also be successfully applied for high frequency vibration analysis.

Successful research can be reported from the Institute of Applied Physics in the Netherlands where the modelling of ship structures and experiments based on the principle of reciprocity are applied for the prediction of sound levels to be expected aboard ships.

Noise levels to which crew and personnel is exposed is an important issue and of great concern for the ship designer.

Ship design considerations concerning noise reduction, noise propagation and damping, are reported in current literature.

Since cavitation is a main source for the noise, depressurized experimental facilities are a necessity for the experimental research in acoustics. Reciprocity measurements as applied for noise investigations may also be used for the determination of ship vibrations.

## 4.2 *Statistical methods* [4.23–4.29]

In general two types of statistical analyses on the ship vibration problem can be distinguished.

One type dealing with a large population of ships and ship types on which vibration phenomena have been observed. Together with information about the afterbody shape and propeller geometry, model measured pressure fluctuations and shaft forces a statistical relation may be obtained between excitation and ship vibration, so that design criteria can be developed.

Another type is dealing with the principle of statistics when one ship structure is tried to be analyzed. Dynamic properties are described in a statistical manner, in particular local systems. A deterministic input or a random input being characterized by a spectral frequency distribution, may be applied. Both types of analysis will be dealt with shortly in this chapter.

In order to shorten the long way of analysis of excitation forces and vibration response, and to enable the ship designer in a very early stage of his design to judge the vibration aspects, on several institutions a statistical analysis of existing ships on their vibration characteristics has been performed, so that working with several parameters and criteria insight can be gained about the risk of unacceptable vibrations. Important parameters are: wake distribution, cavitation, clearance, block coefficient, pressure fluctuation, integrated force fluctuation, vibration amplitude of aft peak, etc. Promising results are reported in [4.23, 4.26, 4.29].

The accuracy, confidence and spread are dependent on the starting parameters and the predicted phenomenon. From pure geometrical parameters, block coefficient, screw aperture or clearance, it is hard to have a firm prediction of the local vibration level. It is a better possibility to predict the vibration level from the fluctuating hull pressure above the propeller. The development of these methods is based on the fact that it is practically impossible to make firm statements about the vibrations in the design stage by other methods of analysis, and the method is common practice in shipbuilding and finds application for other important characteristics such as resistance, wave response, power-speed relation etc.

It is questionable whether the method gives reliable answers on the long run, in particular when the ship does not belong to the original population of ships on which the analysis is based, caused by basic changes in ship parameters, dus to e.g. economical boundary conditions.

*Another statistical approach* is based on the description of the very many "mass-spring systems" as can be recognized aboard ships being the representation for the local response such as: furniture, panels, plating, piping, cabin floors etc. A first attempt to describe these systems in a statistical way is reported in [4.28], based on theories developed at MIT under the name Statistical Energy Analysis.

### 4.3 *Full coverage and non-specific treatment of the ship vibration problem* [4.30–4.52]

The literature and publications collected in this chapter are in general case studies of special problems aboard ships, focussed on machinery or the deckhouse etc., or general reviewing articles.

Much of the available literature is dealing with full size ship vibration analysis and trouble shooting.

In many casestudies is looked after the correlation between predicted and full-size observed vibrations.

All the subjects mentioned in the previous chapters are mixed in these types of investigations in order to try to find their interrelations and to understand the physical process of vibration generation.

Besides the analysis in general, many publications are focussed on special ship types e.g. tankers, Ro-Ro ships, container ships etc.

Depending on the specialisation of the institute or its staffmembers strong accents are recognized, being the starting point towards the general treatment of the problem of global, regional and local vibrations.

A strong accent on propeller and shaft and engine excitation can be found in [4.44], treating machinery hull interaction problems in the first place. A broader scope is described in [4.42], covering global, regional and local vibration problems.

Another approach may be observed from sophisticated Finite Element Methods for the analysis of the vibratory response of the structure and a completion with a forced vibration analysis after having included the excitation forces from propeller, engine and others.

In other cases the vibratory propeller shaft and hull excitation served as the starting point to come to the coverage of the entire ship vibration problem [4.41].

A number of publications are dealing with the analysis and understanding of the full-size ship vibrations being observed during operational voyages. Sometimes a special problem, experienced aboard the ship is the starting point for these types of investigations and much can be learned about the unexpected phenomena. It helps to complete the map of rational vibration analysis, and to fill in some of the many gaps in our understanding of the problems.

In general in these references propeller excitation, engine excitation and structural response of the hull are considered and comparisons are made with full size experiments.

Besides the importance for the practical ship designer and the value to obtain insight in what is happening aboard the ship, it helps the vibration specialist in improving his prediction methods for ships new to be built. Many times it is well illustrated in the full size comparisons where possible improvements in the prediction technique can be made, or where additional new developments have to take place.

## 5 Conclusive remarks, evaluation and recommendations

The vibration problems of the ship during operational conditions are mainly caused by the running propeller and engine.

Other vibration sources such as slamming, whipping and springing, although of great importance for the design and strength analysis of the ship, can be categorized under "avoidable vibration sources". A slight change in heading will eliminate the vibration problem.

Therefore the evaluation will be focussed on *propeller excited vibrations* and the hull response in the propeller blade-frequency range.

The following outline can be made, see Fig. 6. Each step in this diagram can be seen as a subject of research in order to improve the reliability and extrapolability to full size, and have many unanswered questions.

For the determination of the hull pressure excitation a strong research effort can be noticed by many institutes.

A full experimental determination of these forces on model scale or a carefully checked calculation method seems to be the best way of determining these forces. The propeller cavitation is the main parameter governing the pressure amplitudes.

Criteria as indicated in the figure and proposed by various institutions are based on similar information of sailing ships having an acceptable vibratory operation. Hull dynamics are generally analyzed with finite element methods having advanced possibilities. It must be noticed however that for the dynamic characteristics no special criteria or requirements are indicated except that resonance of larger local systems needs to be avoided (bridge-wing, deckhouses etc.). No special requirements are set for the lower mode natural frequencies. This is mainly due to the fact that not very much can be influenced after the main structure of the ship has been designed. Even larger subsystems are hardly to influence in their dynamic response, although resonance avoidance must be seen as a necessity. Even then no guidelines exist in designing a hull structure having a favourable response characteristic. We simply have to live with what comes out of the forced vibration analysis, and this analysis can only be made when the ship is almost ready for launching. So, building a ship under a contract including a maximum allowable vibration level in living quarters and other spaces, is a risky undertaking, and it must be stressed that the development of a powerful reliable prediction method is a must for future shipbuilding.

This necessity is illustrated by the development of statistical prediction techniques, guiding the designer to a successful ship (Chapter 4.2).

Another critical remark must be made when comparisons are made between calculated, model measured and full size measured pressure fluctuations. Due to the dynamic response of the structure of the model or the full size ship the three mentioned quantities are in principle not comparable. When comparisons between calculations and experimental results are made, hydroelastic interactions need to be taken into consideration. For the judgement of the vibration level aboard ship it must be realised that many systems and details perform vibratory motions and a complete description of the vibratory behaviour includes a statistical distribution of local systems and vibratory displacements of significant details. It is difficult to define "the" vibration level, and it is suggested to describe the predicted vibration levels in statistical parameters and compare them with a statistical interpretation of the internationally adopted absolute norm developed by I.S.O.

**Recommendations**

1. It is recommended that uncertainties in the prediction of the propeller generated hull pressure fluctuations are eliminated.
   In the practical frequency range (i.e. 5–30 c.p.s. for model scale), model experiments in depressurized facilities suffer from an unknown dynamic response of the model structure.
   The measured pressures are partly distorted by the hull vibration of the model. The measurement of the true pressure excitation requires a model having a lowest natural frequency well above (5–10 times) the maximum frequency of interest (say 200 Hz). This leads to an impossibility and other ways of experiments are necessary. With a too weak model the *response* on the thrue excitation is measured, in this case the response of the *model-structure.* (The response consists of a mixture of vibratory motions, vibratory pressures due to the surrounding water, e.g. added mass, and a remainder of the thrue excitation pressures). A possible solution may be found in the inversion of the response of the model. The fortunate condition exists, that for a model a dynamic calibration is possible. From this calibration the response functions are known. An inversion of this calibration may lead to the possibility to calculate the thrue propeller generated hull pressure fluctuations from the measured response of the model structure. In fact the problem is similar to that of the prediction of the full size hull vibrations from the hull pressure excitation. Since the hull is a spatially distributed construction it is also necessary to determine the spatially distributed pressure fluctuations. Reduction to a simple force is not allowed for a meaningful analysis.
2. It is recommended that besides the existing criteria on the hydrodynamic excitations (hull and shaft forces) a criterion on global structural vibrations will be developed, to eliminate as far as possible the uncertainties the ship designer faces when a ship is designed and constructed. When the structure of the hull and the lay-out of the ship is known in an advanced design stage, an approximate calculation of the global vibration characteristics is possible. Together with the hull excitation from the propeller an analysis can be made of the main structural forced vibration level, being the input for the analysis of structural details such as panels, floors, furniture etc. The last mentioned types of vibration are nowadays subject for international evaluation (I.S.O. Standard). Based on this standard, it is recommended to develop a criterion for the global forced vibration level.
3. It is recommended that the various F.E. calculation procedures in use in various institutions are compared for their validity i.e. beam approximation, twodimensional ship representations, threedimensional calculations, effects of a coarse and a fine mesh for F.E. approximations.
4. It is recommended, since human sensitivity for vibrations is strong coupled to audible noise in the working areas, to develop internationally a combined criterion for environmental *noise and vibrations.*
5. It is recommended to deduce from the more sophisticated techniques of analysis a simpler method in order to arrive at a method applicable in the design stage, using statistical techniques to describe more or less all the details of the ship structure that are impractical to model with the F.E. approximation.
6. It is recommended for the shipbuilder and shipowner to realize that, in order to arrive at a sound structure of the ship's hull from a point of view of vibration, it is necessary
   - to give priority to the main structure of the ship
   - to have this structure designed not only from a point of view of strength but from a point of view of stiffness
   - to have the lay-out of cabins and working areas adapted to this main structure
   - to have structural supports of details and outfit designed on a stiffness criterion.
7. It is recommended for the yard management to adapt the timing of the construction of the ship on the yard to the requirements of the vibration analyst, to make an "on-time" vibration prediction possible, and for the yard to make proper modifications possible if necessary.

## 6 Acknowledgement

The author wishes to express his appreciation for the overwhelming number of reactions obtained from the various institutions upon his request to send recent information about ship vibration research for the assemblage of this report.

A full list of respondents is given in the attached list.

### List of respondents

Prof. B. Johnson, Dr. S. M. Calisal
Naval Systems Engineering Dept.
U.S. Naval Academy
ANNAPOLIS, Maryland 21402 - USA

Dr. F. N. Biewer
Offshore Technology Corporation
578 Enterprise Street
ESCONDIDO, California 92025 - USA

Dr. D. Liu
American Bureau of Shipping
65 Broad Way
NEW YORK, N.Y. 10006 - USA

Prof. W. Vorus
Dept. of Naval Architecture
University of Michigan
ANN ARBOR, Michigan 48105 - USA

Dr. W. B. Morgan
David Taylor Ship Research and Development Center
Navy Department, Code 154
BETHESDA, Maryland 20084 - USA

Prof. D. Faulkner
Dept. of Naval Architecture and Ocean Engineering
The University
GLASGOW G12 8QQ - UK

Dr. C. S. Smith, Mr. J. D. Clark
Naval Construction Research Etablishment
St. Leonard's Hill
DUNFIRMLINE FIFE, Scotland KY11 5PW - UK

Prof. R. E. D. Bishop, Dr. W. G. Price
University College
Dept. of Mech. Engineering
LONDON - UK

Prof. J. B. Caldwell
Dept. of Naval Architecture and Shipbuilding
The University of Newcastle upon Tyne
Armstrong Building
Queen Victoria Road
NEWCASTLE UPON TYNE NE1 7RU - UK

Dr. G. Ward
The British Ship Research Association
Wallsend Research Station
WALLSEND, Tyne and Wear NE28 6UY - UK

Mr. E. P. Lover, Mr. B. N. Steele
Admiralty Marine Technological
Etablishment, Hydrodynamic Dept. (Haslar)
GOSPORT PO12 2AG - UK

Prof. Dr. Ing. S. Schuster
Versuchsanstalt für Wasserbau und Schiffbau
Müller-Breslau-str. 1
1000 BERLIN 12 - BRD

Prof. Dr. Ing. S. Weiss
Forschungszentrum des Deutschen Schiffbaus
An der Alster 1
2 HAMBURG 1 - BRD

Mr. E. A. Pless
Germanischer Lloyd
Vorsetzen 32
D-2000 HAMBURG 11 - BRD

Prof. H. G. Schultz
Technische Hochschule Aachen
Eilfschornsteinstrasse 18
5100 AACHEN - BRD

Prof. K. A. Reckling
Institut für Mechanik
Technische Universität Berlin
Strasse des 17 Juni 135
1000 BERLIN 12 - BRD

Dr. E. A. Weitendorf
Hamburgische Schiffbau Versuchanstalt GmbH
164 Bramfelderstrasse
HAMBURG 60 - BRD

Prof. Dr. Ing. O. V. Grim
Institut für Schiffbau
Universität Hamburg
Lämmersieth 90
2000 HAMBURG 60 - BRD

Prof. J. Fukuda
Dept. of Naval Architecture
Faculty of Engineering
Kyushu University
Hakozaki,Higashi-Ku
FUKUOKA 812 - Japan

Mr. K. Tamura
Nagasaki Technical Institute
Mitsubishi Heavy Industries Ltd.
1-1 Akunoura-Machi
NAGASAKI 850-91 - Japan

Dr. S. Nakamura
University of Osaka
Yamadi-Kami
Suita-Shi
OSAKA 565 - Japan

Prof. Y. Yamamoto, Dr. H. Oktsubo
Dept. of Naval Architecture
Faculty of Engineering
University of Tokyo
7-3-1 Hongo, Bunkyo-Ku
TOKYO 113 - Japan

Dr. Y. Yamanouchi
Mitsui Engineering & Shipbuilding Co. Ltd.
6-4, Tsukiji 5-Chome, CHUO-KU
TOKYO 104 - Japan

Mr. K. Matsumoto
Hitachi Zosen
Hitachi Shipbuilding and Engineering Co.
S, 1-Cho, Chikko Shin-Machi
Sakai City, OSAKA - Japan

Dr. K. Yokoo
Shipbuilding Research Centre of Japan
1-3-8 Mejiro Toshima-Ku
TOKYO 171 - Japan

Dr. R. Tasaki
Ishikawajima-Harima Heavy Industries Ltd.
1, Shinnakahara-Cho, Isogo-Ku
YOKOHAMA 235 - Japan

Prof. M. Kawakami
Dept. of Naval Architecture
Faculty of Engineering
Hiroshima University
Senda-Machi, 3-Chome
HIROSHIMA CITY - Japan 730

Dr. I. Yamaguchi
Nippon Kaiji Kyokai
2-17-26, Akasaka, Minato-Ku
TOKYO 107 - Japan

Mr. G. C. Volcy
Bureau Veritas
31, rue Henri-Rochefort
75821 PARIS Cédex 17 - France

Prof. E. Steneroth
Division of Naval Architecture
Royal Institute of Technology
10044 STOCKHOLM 70 - Sweden

Dr. H. Edstrand
Statens Skeppsprovningsanstalt
Box 24001
S-400 22 GÖTEBORG 24 - Sweden

Mr. O. Bjorheden
KMW Marine Laboratory
AB Karlstads Mekaniska Werkstad
S-681 01 KRISTINHAM 1 - Sweden

Prof. W. Faltinsen
Division of Ship Hydrodynamics
The University of Trondheim
7034 TRONDHEIM-NTH - Norway

Dr. E. Huse
Skipmodelltanken
Ship Research Institute
P.O. Box 4125 Valintinlyst
N-7001 TRONDHEIM - Norway

Prof. Dr. Ing. H. Schwanecke
Institut für Schiffstheorie
Technische Universität Wien
Getreidemarkt 9
A-1060 WIEN - Austria

Dr. I. Senjanovic
Faculty of Mechanical Engineering and Naval Architecture
University of Zagreb
5, Dure Salaja
P.O. Box 194
41001 ZAGREB - Yugoslavia

Dr. P. Bogdanov
Bulgarian Ship Hydrodynamics Centre
VARNA 9003 - Bulgaria

Ing. G. Georgiev
Shipbuilding Institute
D. Blagoev.str. 128
VARNA - Bulgaria

Prof. E. P. Wierzchowski
Polish Register of Shipping
Ul. Waly Piastowskie 24
Skrytka Pocztowa 445
80-958 GDANSKI 1 - Poland

Mr. W. Ojak
Centrum Techniki Okretowej
Ship Design and Research Centre
Ul. Waly Plastowskie 1
80-958 GDANSKI 1 - Poland

Dr. W. Santini
Registro Italiano Navale
Via Corsica 12
16128 GENOVA - Italy

Mr. S. T. Mathews
Marine Dynamics & Ship Laboratory
National Research Council
Bldg. M-22 OTTAWA, Ontario K1A OR6 - Canada

Prof. Dr. Kruppa
Institut für Schiffbau
Wismarsche Strasse 6/7
X 25 ROSTOCK 1 - DDR

Prof. Dr. W. Wiebeck
Universität Rostock
Sektion Schiffstechnik
Albert-Einstein-Strasse
25 ROSTOCK - DDR

Prof. P. T. Pedersen
Department of Shipbuilding
Technical University of Denmark
Bygning 101 E
2800 LYNGBY - Denmark

Dr. Ir. M. W. C. Oosterveld
Ned. Scheepsbouwkundig Proefstation
Postbus 28
6700 AA WAGENINGEN - The Netherlands

Dr. Ir. W. van Gent
Ned. Scheepsbouwkundig Proefstation
Postbus 28
6700 AA WAGENINGEN - The Netherlands

Ir. F. Pangalila
Ned. Maritiem Instituut
Postbus 1555
3000 BN ROTTERDAM - The Netherlands

Ir. J. Smit
Rijn-Schelde-Verolme
Machinefabrieken en Scheepswerven b.v.
Project Department
Prof. Gerbrandyweg 25
3180 AA ROZENBURG - The Netherlands

**References**

*Chapter 1, section 1.1, par. 1.1.1*

On hull shape and wake:

1.01 R. RUTHERFORD, Aft End Shaping to Limit Vibration. Transactions of the North East Coast Institution of Engineers and Shipbuilders, March 1979.

1.02 W. VAN GENT and J. VAN DER KOOIJ, Influence of hull inclination and hull-duct clearance on performance, cavitation and hull excitation of a ducted propeller. Part I. Monograph published by the Netherlands Maritime Institute, M4, April 1976.

1.03 T. FUJITA, On the Flow Measurement in High Wake Region at the Propeller Plane. Report of Nagasaki Technical Institute, Mitsubishi Heavy Industries Ltd., 1977.

1.04 A. Y. ODABASI, A note on wake scaling in cavitation testing. The Naval Architect, July 1977.

1.05 J. E. KERWIN, S. D. LEWIS and S. KOBAYASHI, Systematic Experiments to Determine the Influence of Skew and Rake on Hull Vibratory Excitation Due to Transient Cavitation. S.N.A.M.E. and S.S.C., Ship Vibration Symposium Oc. 1978, Arlington, Va., U.S.A.

Condition of medium:

1.06 E.-A. WEITENDORF and A. P. KELLER, A Determination of the Free Air Content and Velocity in Front of the "SYDNEY EXPRESS"-Propeller in Connection with Pressure Fluctuation Measurements. 12th Symp. on Naval Hydrodynamics, Office of Naval Research, The National Research Council, David Taylor Ship Research and Development Center, Washington, D.C., June 5-9, 1978.

1.07 E.-A. WEITENDORF, Conclusions from full scale and model investigations of the free air content and of the propeller excited hull pressure amplitudes due to cavitation. ASME Symposium on Cavitation Inception, New York, Dec. 1979.

On cavitation, pressure field, fluctuating pressures:

1.08 T. HOSHINO, Pressure Fluctuation Induced by a Spherical Bubble Moving with Varying Radius. Report of Nagasaki Technical Institute, Mitsubishi Heavy Industries Ltd., 1977.

1.09 L. NOORDZIJ, Pressure Field Induced by a Cavitating Propeller. Int. Shipb. Progress, Vol. 23, No. 260, April 1976.

1.10 E.-A. WEITENDORF, Kavitationseinflüsse auf die vom Propeller induzierten Druckschwankungen. Bericht Nr. 338, Institut für Schiffbau der Universität Hamburg, Sept. 1976.

1.11 E.-A. WEITENDORF, Der Kavitierende Spitzenwirbel eines Propellers und die daraus resultierenden Druckschwankungen. Schiffstechnik, Band 24, 1977.

1.12 G. KUIPER, Modelling of Tip Vortex Cavitation in Ship Propellers. 4th Lips Propeller Symposium, Drunen - The Netherlands, Oct. 1979.

1.13 L. TAMBORSKI, Study on the Fluctuating Hull Surface Forces Induced by a Cavitating Propeller. 4th Lips Propeller Symposium, Drunen - The Netherlands, Oct. 1979.

1.14 G. KUIPER, Some Experiments with Distinguished Types of Cavitation on Ship Propellers. ASME Symposium on Cavitation Inception, New York, Dec. 2-7, 1979.

1.15 N. CHIBA and T. HOSHINO, Effect of Unsteady Cavity on Propeller-Induced Hydrodynamic Pressure. Nagasaki Experimental Tank, Mitsubishi Heavy Industries, 1977.

1.16 P. VAN OOSSANEN and J. VAN DER KOOY, Vibratory Hull Forces Induced by Cavitating Propellers. Trans. RINA, Vol. 116, No. 2, 1973.

1.17 J. VAN DER KOOY, Experimental Determination of Propeller-Induced Hydrodynamic Hull Forces in the NSMB Depressurised Towing Tank. RINA Symposium on Propeller-Induced Ship Vibration, London, Dec. 1979, Paper No. 6.

1.18 G. DYNE and M. HOEKSTRA, Propulsion, Cavitation and Propeller-Induced Pressure Fluctuations of a Tanker (Comparative Tests in SSPA Cavitation Tunnel No. 2 and NSMB Depressurized Towing Tank), SNAME Spring Meeting, June 1976.

1.19 C.-A. JOHNSSON, O. RUTGERSSON, S. OLSSON and O. BJÖRHEDEN, Vibration Excitation Forces from a Cavitating Propeller - Model and Full Scale Tests on a High Speed Container Ship. 11th Symposium on Naval Hydrodynamics, London 1976. (Also SSPA Publ. No. 78, 1976).

1.20 H. LINDGREN and C.-A. JOHNSSON, On the influence of Cavitation on Propeller Excited Vibratory Forces and Some Means of Reducing its Effect. 1st Symposium on Practical Design in Shipbuilding (PRADS), Tokyo 1977.

1.21 G. BARK and W. VAN BERLEKOM, Experimental Investigations of Cavitation Noise. 12th Symposium of Naval Hydrodynamics, Washington D.C., June 1978. See also SSPA Publication No. 83.

1.22 H. LINDGREN and E. BJÄRNE, Ten Years of Research in SSPA Large Cavitation Tunnel. SMM/University Conference, Newcastle, Sept. 1979.

1.23 J. GLOVER and G. PATIENCE, Aspects of the Design and Application of Off-Loaded Tip Propellers. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 7.

1.24 J. W. ENGLISH, Cavitation Induced Hull Surface Pressures - Measurements in a Water Tunnel. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 5.

1.25 C.-A. JOHNSSON, Some Experiences from Vibration Excitation Tests in the SSPA Large Cavitation Tunnel. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 4.

1.26 A. JONK and J. VAN DER KOOY, Cavitation phenomena and propeller-induced hull pressure fluctuations of a third-generation containership. Monograph published by the Netherlands Maritime Institute, M12, May 1977.

1.27 M. R. WILLS, G. H. SOLE and M. G. ANTHONY, Propeller Excited Vibration - the Practical Application of Theoretical Methods to Ship Design - Part I, Excitation. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 12.

1.28 W. S. VORUS, Calculation of Propeller-Induced Vibratory Hull Forces, Force Distribution, and Pressures; Free-Surface Effects. Journal of Ship Research, Vol. 20, No. 2, June 1976, pp. 107-117.

1.29 W. S. VORUS, J. P. BRESLIN and Y. S. TEIN, Calculation and Comparison of Propeller Unsteady Pressure Forces on Ships. SNAME, paper presented at Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 16-17, 1978.

1.30 B. D. COX, W. S. VORUS, J. P. BRESLIN and E. P. ROOD, Recent Theoretical and Experimental Developments in the Prediction of Propeller-Induced Vibratory Forces on nearby Boundaries. Paper presented at 12th Symp. on Naval Hydrodyanamics, Office of Naval Research, Washington D.C., June 1978.

1.31 J. P. BRESLIN, S. TSAKONAS and D. VALENTINE, A Method for Predicting Effects of Propeller-Hull Configurations on Vibratory Excitation of Ships. Euromech 122, 1979.

1.32 J. H. MCCARTHY, On the Calculation of Thrust and Torque Fluctuations of Propellers in Nonuniform Wake Flow. NSRDC Report 1533, 1961.

1.33 T. HANAOKA, Hydrodyanamics of an oscillating screw Propeller. 4th Symp. on Naval Hydrodynamics, 1962.
1.34 Y. YAMAZAKI, On the theory of unsteady propeller forces. 7th Symp. on Naval Hydrodynamics, Rome 1968.
1.35 J. E. KERWIN and C. S. LEE, Prediction of Steady and Unsteady Marine Propellers Performance by Numerical Lifting Surface Theory. SNAME, Vol. 86, 1978, pp. 218-253.
1.36 K. P. FLEISCHER and S. SCHUSTER, Kavitationsversuche mit einem angetriebenen Schiffsmodell. Hansa, 113. Jahrgang Nr. 24, 1976.

On full scale pressure fluctuations:

1.37 K. O. HOLDEN, A. SØRENSEN, S. ANDERSEN and D. KARLSEN, Propeller Blade Cavitation as a Source of Vibrations. Full Scale Experiences. Norwegian Maritime Research No. 4, 1974.
1.38 R. A. P. J. SCHULZE, Full-scale hull pressure measurements on the afterbody of the third-generation containership s.s. "Nedlloyd Delft". Monograph published by the Netherlands Maritime Institute, M11, April 1977.

General:

1.39 H. SCHWANECKE, Verminderung der vom Propeller hervorgerufenen hydrodynamischen Schwingungserregungen des Schiffskörpers. Hansa, 112. Jahrgang Nr. 22, 1975.
1.40 E. J. GLOVER, J. F. THORN and L. HAWDON, Propeller Design for Minimum Hull Excitation. Trans. RINA, Spring Meeting 1979.
1.41 E. HUSE, Propeller induced excitation forces and vibrations, cavitation noise and erosion. Symposium on Advances in Marine Technology, Trondheim 1979.
1.42 O. H. BURNSIDE, D. D. KANA and F. E. REED, Summary of a Design Procedure for Minimizing Propeller-Induced Vibration in Ships. Euromech 122, 1979. Paris.

*Chapter 1, section 1.1, par. 1.1.2*

On propeller blade and shaft forces (experimental):

1.43 Measurement of Propeller Bearing Force. (In Japanese). 1978.
1.44 D. SCHMIDT, Bestimmung instationärer Propellerkräfte am Modell eines Containerschiffes. Schiffbauforschung, 18. Jahrgang Heft. 3/4, 1979.
1.45 S. NAKAMURA and S. NAITO, Propulsive Performance of a Container Ship in Waves. JSNA Kansai Japan, No. 158 Sept. 1975; No. 159 Dec. 1075 and No. 162 Sept. 1976.
1.46 S. NAITO and S. NAKAMURA, Open Water Characteristics and Load Fluctuation of Propeller at Racing Condition in Waves. (In Japanese).
1.47 J. BLAUROCK, Untersuchung über das Kavitationsverhalten und die instationäre Belastung von Schiffspropellern bei Schräganströmung. Bericht Nr. 66/1976, Forschungszentrum des Deutschen Schiffbaus, Hamburg.
1.48 R. J. BOSWELL, S. D. JESSUP and J. J. NELKA, Experimental Unsteady and Time-Average Loads on the Blades of a CP Propeller Behind a Model of the DD-963 Class Destroyer. Paper presented to the Propellers '78 Symposium, SNAME, Virginia Beach, Virginia, 24-25 May 1978.
1.49 S. HYLARIDES, Model Tests on Hydrodynamics of Propeller Blade Vibrations. SNAME Symposium Propellers '78, Virginia Beach, Virginia, May 1978.
1.50 J. BLAUROCK, Ermittlung der am Einzelflügel eines Propellers auftretenden Kraftschwankungen. Bericht Nr. 71/1977, F.D.S. Hamburg.
1.51 T. SUHARA, H. YUMOTO, T. KUMAI, Y. SUGIMURA and Y. SAKURADA, Model Tests by a New Technique of Single Blade Measurement on Overlapping propeller Bearing Force. (In Japanese).
1.52 O. BJÖRHEDEN, Highly Skewed Controllable Pitch Propeller. Paper read at the 73rd Annual Meeting of the German Ship Technical Society, STG, Berlin, 22-25 Nov. 1978 (in German).
1.53 N. O. HAMMER and R. F. McGINN, Highly Skewed Propellers - Full Scale Vibration Test Results and Economic Considerations. SNAME and SSC Ship Vibration Symposium, Oct. 1978, Arlington, Va., U.S.A.
1.54 O. BJÖRHEDEN, Vibration Performance of Highly Skewed CP Propellers. RINA, Symposium on Propeller Induced Ship Vibration, London, Dec. 1979.
1.55 M. YAMAGUCHI, Experimental Investigation on Propeller Exciting Forces (Eng.) Symp. in Hydrodynamics of Ship and Offshore Propulsion Systems, March 1977.

On propeller blade and shaft forces (theoretical):

1.56 W. VAN GENT, On the Use of Lifting Surface Theory for Moderately and Heavily Loaded Ship Propellers. Publication No. 536, NSMB Wageningen.
1.57 W. VAN GENT, Unsteady Lifting-Surface Theory for Ship Screws: Derivaton and Numerical Treatment of Integral Equation. Journal of Ship Research, Vol. 19, Dec. 1975, pp. 243-253.
1.58 M. G. PARSONS and J. E. GREENBLATT, Optimization of Propeller Skew Distribution to Minimize the Vibratory Forces and Moments Acting at the Propeller Hub. University of Michigan, Dept. of Naval Arch. and Marine Engr., Report No. 206, Dec. 1978.
1.59 T. SASAJIMA, Usefulness of Quasi-Steady Approach for Estimation of Propeller Bearing Forces. SNAME Propellers '78 Symposium, Virginia Beach, Virginia, May 1978.
1.60 M. YAMAGUCHI, On an Estimation Method of Propeller Exciting Force and its Application (Japanese) Jour. of the Kansai Society and Naval Architects No. 173, June 1979.
1.61 S. HYLARIDES and W. VAN GENT, Hydrodynamic Reactions to Propeller Vibrations. Conference on Operational Aspects of propulsion Shafting Systems, May 1979, London.
1.62 S. TSAKONAS and W. R. JACOBS, Propeller-Duct Interaction Due to Loading and Thickness Effects. SNAME Propellers '78 Symposium, Virginia Beach, Virginia, May 1978.

Miscellaneous:

1.63 The effect of cavitation on the dynamic propeller forces of a Ro-Ro vessel. Report No. W13014-1-VT, NSMB Wageningen, March 1978.
1.64 H. OBEREMBT, Veränderung der hydrodynamischen Kräfte eines Propellers bei Berücksichtigung der Blattelastizität und Berechnung der freien Schwingungen eines Propellerblattes. Schiffstechnik, Bd. 18, Heft 90, 1971.

*Chapter 1, section 1.1, par. 1.1.3*

On wake criteria:

1.65 P. A. FITZSIMMONS, Propeller excited vibration: a cavitation criterion for the assessment of scaled model wakes. Int. Shipb. Progress, Jan. 1978.

1.66 A. Y. ODABASI and P. A. FITZSIMMONS, Alternative methods for wake quality assessment. Int. Shipb. Progress, Vol. 25, No. 282, Feb. 1978.

On pressure criteria:

1.67 H. SCHWANECKE, Eine Bewertungsgrösse für die Schwingungserregung des Schiffskörpers durch das instationäre Propeller-Druckfeld. Schiff und Hafen/Kommandobrücke, 28. Jahrg., Heft 11, 1976.
1.68 Report of the Propeller Committee of the 15th ITTC, The Hague, 1978, issued by NSMB Wageningen.
1.69 C. A. CARLSEN, K. SKAAR and M. KUCHARSKI, Propeller Induced Ship Hull Vibration: Design Stage Calculation with Sufficient Accuracy at a Reasonable Cost. Euromech 122, 1979.

General:

1.70 Propeller Committee Report - Task III C. Response to the Propeller Committee Request for Criteria for Assessing the Acceptability of Hydrodynamic Vibratory Excitation Caused by Marine Propellers. 15th ITTC, The Hague, 1978.
1.71 M. MEEK, H. RITTER and G. WARD, General View of UK Research on Propeller-Hull Interaction and Associated Ship Vibration. RINA, Symposium on Propeller Induced Ship Vibration, London, Dec. 1979.
1.72 T. SKAAR and A. E. RAESTAD, The Relative Importance of Ship Vibration Excitation Forces. RINA, Symposium on Propeller Induced Ship Vibration, London, Dec. 1979.
1.73 H. G. PAYER, Bemerkungen zu den Möglichkeiten und Grenzen der Vorausberechnungen von Schwingungen auf Schiffen. Schiffstechnik 24, 1977, S. 252-268.
1.74 K. KAUBE and H. G. PAYER, Zulässige Schwingungen an Bord von Schiffen - MTK 0058. Statusseminar des BMFT, Hamburg, 26. Sept. 1979.

*Chapter 1, section 1, par. 1.2*

On wave induced vibrations

1.75 F. TASAI, On the Calculation Methods of Wave Induced Vibration of Ships. Trans. West-Japan Society of Naval Architects, No. 48, Aug. 1974.
1.76 M. LINNERT, Zur Berechnung der Torsionsmomentenbelastungen des Schiffskörpers im Seegang. Schiffbauforschung, Bd. 15, Heft 3/4, 1976.
1.77 S. O. SKJØRDAL and O. M. FALTINSEN, A Linear Theory of Springing. Report of Norwegian Institute of Technology, Trondheim, Norway. Published in Journal of Ship Research 1979.
1.78 S. O. SKJØRDAL, A rational Ship Theory Approach for the Evaluation of Springing, Dr. ing. thesis, Division of Marine Hydrodynamics, Norwegian Institute of Technology, Trondheim, January 1978.
1.79 J. JENSEN, JUNCHER and PEDERSEN, P. TERNDRUP, Wave-Induced Bending Moments in Ships - A Quadratic Theory. The Royal Institution of Naval Architects, Supplementary Papers, July 1979, also in Transactions 1979.
1.80 J. JUNCHER JENSEN AND P. TERNDRUP PEDERSEN, Vertical Response and Flexible Ships in Waves. Euromech 122, Numerical Analysis of the Dynamic of Ship Structures, Paris Sept. 1979.
1.81 T. A. ACHTARIDES, Wave excited two-node Vertical Resonant Vibration (Springing) of Flexible Ships. Marine Technology 1979.
1.82 H. SÖDING, Springing of Ships. Considerations and Computations for the Development of a Forecasting Procedure. Publ. of the Technical University Hannover No. 7, March 1975.
1.83 O. GRIM, Elastische Schwingungen des Schiffes, erregt durch nicht-lineare Kräfte des natürlichen, unregelmässigen Seegangs. Bericht Nr. 325, Institut für Schiffbau der Universität Hamburg, März 1975.
1.84 N. GUYEN KET, B. DUVAL et M. HUTHER, Estimation des risques de slamming par calcul. ATMA, Session 1979, Paris.
1.85 M. KAWAKAMI and J. MICHIMOTO, On the Stochastic Prediction of Whipping Vibration of Ship due to Slamming Impact, TSNA, West-Japan, 52 (1976) (in Japanese).
1.86 M. KAWAKAMI and K. TANAKA, Stochastic Prediction of Impact Pressure due to Shipping Green Sea on Fore Deck of Ship, TSNA, West-Japan, 53 (1977) (in Japanese).
1.87 M. KAWAKAMI and J. MICHIMOTO, Prediction of Long-Term Whipping Vibration Stress due to Slamming of Large Full Ship in Rough Seas, ISP, 24, 272 (1977).
1.88 K. TANAKA and M. KAWAKAMI, Stochastic Prediction of Whipping of a Very High Speed Ship due to Slamming, TSNA, West-Japan, 56 (1978) (in Japanese).
1.89 M. KAWAKAMI, H. NOBUKAWA, K. TANAKA, J. MICHIMOTO and Y. SHIRAKI, On Transient Vibration of Stern Body Structure of Car Ferry due to Wave Impact on Aft Bottom, TSNA, West-Japan, 57 (1979) (in Japanese).
1.90 Y. YAMAMOTO, M. FUJINO and T. FUKASAWA, Motion and Longitudinal Strength of a Ship in Head Sea and the Effects of Non-Linearities. (In Japanese).
1.91 V. S. APOSTOLOV, Ship vibration induced by irregular waves. Thesis of dissertation, Leningrad Shipbuilding Institute, 1968. (In Russian).

*Chapter 1, section 1, par. 1.3*

On prime movers:

1.92 J. ASMUSSEN und H. G. PAYER, Schwingungstechnische Grenze für Hauptmotoren geringer Zylinderzahlen. Bericht Nr. 88/1979, F.D.S. Hamburg.
1.93 J. KOLENDA, Über die Genauigkeit der linearen Bewegungsgleichungen von elastisch gelagerten Dieselmotoren. Schiffbauforschung, 18. Jahrgang (1979), Heft Nr. 3/4.

*Chapter 2, section 2.2*

On hydrodynamic effects:

2.01 N. FL. MADSEN, The Natural Frequency of Prismatic Plate Structures Submerged in a Liquid. Sonderheft GAMM-Tagung Lyngby 1977, Band 58, 1978.
2.02 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, Hydrodynamic coefficients of some heaving cylinders of arbitrary shape. Int. J. Numer. Methods Eng. 13, 1978, pp. 17-33.
2.03 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, The representation of hull sections and its effects on estimated hydrodynamic actions and wave responses. Trans. RINA 121, 1978, pp. 115-126.
2.04 R. E. D. BISHOP and W. G. PRICE, The generalised antisymmetric fluid forces applied in a seaway. Int. Shipb. Progress 24, 1977, pp. 3-14.
2.05 G. C. VOLCY, P. MOREL, M. BEREAU and K. TANIDA, Some studies and researches related to the hydro-elasticity of steel work. Euromech 122, Numerical Analysis of the Dynamics of Ship Structures, Palaiseau, France, Sept. 1979.
2.06 S. HYLARIDES, Some Hydrodynamic Considerations of Propeller Induced Ship Vibrations. ASME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

2.07 C. V. Betts, R. E. D. Bishop and W. G. Price, A survey of hull damping. Trans. RINA 119, 1977, pp. 125–142.
2.08 C. V. Betts, R. E. D. Bishop and W. G. Price, The symmetric generalised fluid forces applied to a ship in a seaway. Trans. RINA 119, 1977, pp. 265–278.
2.09 N. Fl. Madsen, On the Influence of Three-Dimensional Effects and Restricted Water Depth on Ship Hull Vibration. I.S.P. 25 No. 286, June 1978.
2.10 M. Fujino and M. Sugita, On the Added Mass of a Two-dimensional Rectangular Cylinder Vibrating in Parallel to the Free Surface and in a Perpendicular Direction in Restricted Waters. (In Japanese).
2.11 Y. Yamamoto, T. Nakano and N. Mitsuda, Fundamental Studies on Steady Ship Wave Problems by the Finite Element Method (The Second Report). (In Japanese).
2.12 K. Sao, Sway and Roll of an axi-symmetrical body. (In Japanese).
2.13 M. Fujino, The Effects of the Restricted Waters on the Added Mass of a Rectangular Cylinder. 11th Symp. on Naval Hydrodynamics, London, 1976.
2.14 Y. Matsuura and K. Arima, A Calculation Method of Ship Hull Vibration. (In Japanese). March '76, Journal of Kansai Soc. Nav. Arch. Japan.
2.15 Y. Matsuura and K. Arima, A Note on the Added Virtual Mass for Circular Cylinder Vibrating in Water. (In Japanese). Sept. '78, Journal of Kansai Soc. Nav. Arch. Japan.
2.16 Y. Matsuura and K. Arima, A Study on the Added Virtual Mass for Ellipsoid of Revolution in Vertical Vibration in Water. (In Japanese). Dec. '77, Journal of Kansai Soc. Nav. Arch. Japan.
2.17 I. Senjanovic, Determination of Added Mass in Ship Vibration Analysis by the Finite Element Method. Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, 1977.
2.18 T. Agustinovic, Computer Program for Determination of Added Mass in Ship Hull Vibration. Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, 1976.
2.19 T. Agustinovic, Comparation of the Results of Programs for Added Mass and Ship Vibration Calculation. Det norske Veritas Report No. 76-022, 1976.
2.20 T. Agustinovic, Computer Calculation of Virtual Mass in Relation to the Ship Hull Vibrations. Proceedings of 2nd Symposium Theory and Practice of Naval Architecture, Zagreb, 1976.
2.21 E. Langecker, and L. Palm, Zur Anwendung der Korrekturfaktoren der hydrodynamischen Masse nach Kruppa bei Schiffskörperschwingungen. Schiffbauforschung 15, 3/4, 1976.
2.22 K.-P. Schmitz, Bestimmung der Dämpfungsfaktoren für die Berechnung der vertikalen elastischen Schiffskörperschwingungen. Schiffbauforschung 15, 1/2, 1976.
2.23 P. Orsero and J. L. Armand, Added Mass in Ship Hull Vibration: Calculation using Infinite Elements. Euromech 122, 1979.
2.24 G. E. Hearn, Theoretical Treatment of Added Mass in Vibration Calculations. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979.
2.25 O. Grim, Hydrodynamische Masse bei lokalen Schwingungen, insbesondere bei Schwingungen im Bereich des Maschinenraums. Schiff und Hafen 27, Heft 11, 1975.
2.26 M. Huther, M. Dubois and J. M. Planeix, Model studies on the movement of liquid in tanks. Marine Engineers Review, Jan. 1973.
2.27 J. Osouf, Comportement dynamique des gouvernails, ATMA, Session 1976, Paris.
2.28 P. Orsero, Détermination de la masse hydrodynamique entraînée dans les vibrations de navires. ATMA, Session 1977, Paris.
2.29 K. Arima, On the Vertical Vibration of Elastic Bodies Immersed in Water, JKSNA, No. 164 (March '77) (in Japanese) Journal Kansai Soc. of Nav. Arch.
2.30 Y. Matsuura and K. Arima, A Study of the Virtual Mass Reduction Factors J. Values for Ship, HZTR, Vol. 40, No. 2 (June '79) Mitachi Zosen Techn. Rev.
2.31 K. Matsumoto and K. Arima, A Note on the Added Mass of Rectangular Plate, JKSNA, No. 173 (June '79) (in Japanese) Journal of Kansai Soc. Nav. Arch.
2.32 T. Makimata and K. Arima, Added Mass of Flexible Offshore Structures, PJSCE, No. 291 (Nov. '79) (in Japanese) Proc. Jap. Soc. of Civil Engineers.

On global response:

2.33 W. S. Vorus and R. E. Sandström, An Extension of Component Mode Synthesis and its Application to Ship Vibrations. Euromech 122, Paris Sept. 1979.
2.34 I. Senjanovic and R. Grubisic, Coupled Horizontal and Torsional Vibration of Ship Hull with Large Deck Openings. Euromech 122, Paris Sept. 1979.
2.35 C. A. Mota Soares and J. E. Barradas Cardoso, Finite Element Dynamic Analysis of Structures based on the Vlasov Beam Theory. Euromech 122, Paris Sept. 1979.
2.36 J. Juncher Jensen and P. Terndrup Pedersen, Vertical Response of Flexible Ships in Waves. Euromech 122, Paris Sept. 1979.
2.37 R. E. D. Bishop, W. G. Price and P. Temarel, Wave-Induced Antisymmetric Response of Flexible Ship. Euromech 122, Paris Sept. 1979.
2.38 D. Catley and C. Norris, Theoretical Prediction of the Vertical Dynamic Response of Ship Structures using Finite Elements and Correlation with Ship Mobiity Measurements. 11th Symposium ONR, April 1976.
2.39 C. Norris and D. Catley, Application of a Two-Dimensional Finite Element Model to Ship Vertical Vibration and Comparison with Ship Mobility Measurements. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 16.
2.40 K. T. Skaar, Dynamic Behaviour of Ship Structures. Proceedings of 2nd Symposium Theory and Practice of Naval Architecture, Zagreb, 1976.
2.41 T. Agustinovic, The Calculations of Ship Hull Free Transverse Vibration by Finite Element Method and Analysis. Results of Calculations. Proceedings of 2nd Symposium Theory and Practice of Naval Architecture, Zagreb, 1976.
2.42 I. Senjanovic and K. T. Skaar, Phenomena of Ship Vibration. Det norske Veritas Publication No. 88, 1975.
2.43 I. Senjanovic and K. T. Skaar, Problems of Ship Vibration: Present Solutions and Further Investigations. SNAME Spring Meeting, Philadelphia, 1976.
2.44 I. Senjanovic and K. T. Skaar, Problems of Coupling Between Ship Hull and Substructure Vibration. Hansa, No. 20. 1975.
2.45 J. C. Masson and F. Besnier, Modal Synthesis Techniques Application with the ASKA Program to Ship Structures. Bureau Veritas, Paris.
2.46 V. Coric, Methods of Calculation of Ship Hull Vibration, Computer Programs. Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, 1976.
2.47 I. Senjanovic, Numerical Methods for Ship Vibration Analysis by Finite Elements. Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, 1976.

2.48 I. SENJANOVIC, Different Approaches to the Problem of Ship Vibration Analysis. Det norske Veritas, Report No. 76-035, 1976.
2.49 I. SENJANOVIC, Hull Girder Vibration. Det norske Veritas, Report No. 76-099, 1976.
2.50 T. AGUSTINOVIC, Computer Program Specification for the Calculation of Free Transverse Ship Hull Vibration by Finite Element Method and Discussion of the Results. Det norske Veritas, Report No. 76-017, 1976.
2.51 R. GRUBISIC, Coupled Horizontal and Torsional Vibration Analysis of Ships with Large Deck Openings. Proceedings of 3rd Symposium Theory and Practice of Naval Architecture, Zagreb, 1978.
2.52 I. SENJANOVIC, Coupled Horizontal and Torsional Vibration of Ships with Large Deck Openings. Proceedings of 3rd Symposium Theory and Practice of Naval Architecture, Zagreb, 1978.
2.53 L. PALM, Ermittlung der Schubsteifigkeit zur Berechnung höherer Eigenfrequenzen und Eigenformen von vertikalen Schiffskörperschwingungen. Schiffbauforschung 14, 5/6, 1975.
2.54 L. PALM, Berechnung vertikaler Schiffskörpereigenschwingungen. Schiffbauforschung 16, 1/2, 1977.
2.55 K.-P. SCHMITZ, Zur Berechnung der freien gekoppelten Horizontal-Torsions-Schwingungen des Schiffskörpers. Teil 1: Berechnungsmethoden und Programme. Schiffbauforschung 16, 3/4, 1977.
2.56 P. LEHMANN und W. WEHLTE, Einige theoretische und experimentelle Untersuchungen zum Schwingverhalten des werkstoff- und luftgedämpften Euler-Bernoulli-Balkens. Schiffbauforschung 16, 3/4, 1977.
2.57 K.-P. SCHMITZ und U. WORBS, Ein Programm zur Vorausberechnung der freien und erzwungen Vertikalschwingungen des Schiffskörpers. Seewirtschaft 7, 9, 1975.
2.58 R. POSTL, K.-P. SCHMITZ, Beitrag zur Berechnung freier und erzwungener Schiffskörperschwingungen. Wissenschaftliche Zeitschrift der Universität Rostock, 24. Jahrg. 1975, Mathematisch-Naturwissenschaftliche Reihe, Heft 9.
2.59 R. POSTL, Über die Modellfindung zur Berechnung der Schiffskörperschwingungen. Schiffbauforschung 17, 3/4, 1978.
2.60 B. SWITAISKI, Ein Übertragungsverfahren zur Berechnung erzwungener gedämpfter Transversal-Torsions-Schwingungen des Schiffskörpers. Dissertation T.H. Aachen, Juni 1978.
2.61 A. A. LIEPINS, Prediction of propeller induced ship vibration: some structural aspects. Paper Littleton Research and Engineering Corp. Littleton, Mass., U.S.A.
2.62 M. FERIC and B. MEDJA, Possibilities of Vibration Investigation by Means of Vibration Exciter BI 25 Aboard Ship During Building. Proceedings of 3rd Symposium Theory and Practical of Naval Architecture, Zagreb, 1978.
2.63 T. KAWAI, New Discrete Models and their Application to Seismic Response Analysis of Structures. Nuclear Engineering and Design 48 (1978), pp. 207–229.
2.64 T. KAWAI and Y. TOI, New Element Models in Discrete Structural Analysis. JSNA, Japan, Vol. 141, June 1977 and Vol. 143, June 1978.
2.65 K. YOSHIDA and K. ISHIKAWA, Periodic Response of Three Dimensional Floating Framed Structures. (In Japanese).
2.66 Y. TOI and T. KAWAI, A New Discrete Analysis on Dynamic Collapse of Structures. Report of Institute of Industrial Science, University of Tokyo, 1978.
2.67 K. KAGAWA and K. FUJITA, A Study on Higher Mode Vibration of Ships. Report of Nagasaki Technical Institute, Technical Headquarters, Mitsubishi Heavy Industries Ltd.
2.68 K. OHTAKA, Vertical Vibration of Bulk Carrier. Trans. of the West-Japan Society of Naval Architects, No. 56, August 1978.
2.69 P. TERNDRUP PEDERSEN and J. JUNCHER JENSEN, A Program System for Strength and Vibration Calculations for Ship Structures. Procs. 1979 IFIP-IFAC International Conference on Computer Applications in the Automation of Shipyard Operation and Ship Design.
2.70 C. M. R. WILLS, G. H. SOLE and M. G. ANTHONY, Propeller Excited Vibration – the Practical Application of Theoretical Methods to Ship Design. Part II, Response. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 13.
2.71 J. J. JENSEN and N. FL. MADSEN, A Review of Ship Hull Vibration. The Shock and Vibration Digest, Vol. 9, No. 4, 5, 6 and 7, 1977.
2.72 V. APOSTOLOV, On the Determination of Natural Vibration Frequencies of the Supported Beams. Annual report of the Shipbuilding Institute, Varna, 1977.
2.73 S. HYLARIDES, Ship Vibrations. Status report 1976. NSMB Wageningen, Report No. 1110-3-ST.
2.74 S. HYLARIDES, Ship vibration analysis by finite element technique. Part III: Damping in ship hull vibrations. Monograph published by the Netherlands Maritime Institute, M2, March 1976.
2.75 S. HYLARIDES, Damped hull vibrations of a cargo vessel, calculations and measurements. Monograph published by the Netherlands Maritime Institute, M5, May 1976.
2.76 J. L. ARMAND and P. ORSERO, Analytical Identification of Damping in Ship Vibrations from Full-scale Measurements. RINA Symposium of Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 14.
2.77 T. H. OEI, Finite element ship hull vibration analysis compared with full scale measurements. Monograph published by the Netherlands Maritime Institute, M7, July 1976.
2.78 D. HOFFMAN and R. W. VAN HOOFF, Experimental and Theoretical Evaluation of Springing on a Great Lakes Bulk Carrier. I.S.P., Vol. 23, June 1976.
2.79 R. G. KLINE, Springing and Hydroelastic Problems of large Ships. SNAME, 1975.
2.80 H. SÖDING, Springing of Ships. Considerations and Computations for the Development of a Forecasting Procedure. Publ. of the Technical University Hanover No. 7, March 1975.
2.81 M. KAWAKAMI, J. MICHIMOTO and K. KOBAYASHI, Prediction of Long-Term Whipping Vibration Stress due to Slamming of Large Full Ship in Rough Seas. I.S.P., Vol. 24, April 1977.
2.82 R. E. D. BISHOP and W. G. PRICE, A general method of structural analysis for marine structures and vehicles. J. Mech. Eng. Sci. 17, 1975, pp. 363–365.
2.83 R. E. D. BISHOP and W. G. PRICE, Ship strength as a problem of structural dynamics. Naval Architect 2, 1975, pp. 61–63.
2.84 R. E. D. BISHOP and W. G. PRICE, Antisymmetric response of a box-like ship. Proc. Roy. Soc. London A349, 1976, pp. 157–167.
2.85 R. E. D. BISHOP and W. G. PRICE, On the transverse strength of ships with large deck openings. Proc. Roy. Soc. London A349, 1976, pp. 169–182.
2.86 R. E. D. BISHOP and W. G. PRICE, On modal analysis of ship distortion in still water. Trans. RINA 119, 1976, pp. 151–160.
2.87 R. E. D. BISHOP and W. G. PRICE, On the relationship between "dry modes" and "wet modes" in the theory of ship response. J. Sound Vib. 45, 1976, pp. 157–164.

2.88 R. E. D. BISHOP and W. G. PRICE, Allowance for shear distortion and rotatory inertia of ship hulls. J. Sound Vib. 47, 1976, pp. 303-311.
2.89 R. E. D. BISHOP and W. G. PRICE, Coupled bending and twisting of a Timoshenko Beam. J. Sound Vib. 50, 1977, pp. 469-477.
2.90 R. E. D. BISHOP and W. G. PRICE, A note on structural damping of ship hulls. J. Sound Vib. 56, 1978, pp. 495-499.
2.91 R. E. D. BISHOP and W. G. PRICE, The vibration characteristics of a beam with an axial force. J. Sound Vib. 59, 1978, pp. 237-244.
2.92 R. E. D. BISHOP and W. G. PRICE, An investigation into the linear theory of ship response to waves. J. Sound Vib. 62, 1979, pp. 353-363.
2.93 R. E. D. BISHOP, R. K. BURCHER and W. G. PRICE, Some suggestions concerning linear theory of aero- and hydroelasticity. Strojnicky Casopis 27, 1976, pp. 14-22.
2.94 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, The dynamical characteristics of some dry hulls. J. Sound Vib. 54, 1977, pp. 29-38.
2.95 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, A unified dynamic analysis of ship response to waves. Trans. RINA 119, 1977, pp. 363-390.
2.96 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, Wave-induced response of a flexible ship. I.S.P. 24, 1977, pp. 284-295.
2.97 C. U. BETTS, R. E. D. BISHOP and W. G. PRICE, A Survey of Internal Hull Damping. RINA, 1976.
2.98 T. NAGAI and S.-L. CHUANG, Review of Structural Response Aspects of Slamming. Journal of Ship Research, Vol. 21, No. 3, Sept. 1977.
2.99 M. KAWAKAMI and T. Tanaka, Stochastic Prediction of Whipping Vibration of Very High Speed Ship due to Slamming. Euromech 122, Paris 1979.
2.100 K. KAGAWA, K. OHTAKA and M. ONOUE, A Study of Wave-Induced Vibrations. Nagasaki Techn. Inst., Techn. Headquarters, Mitsubishi Heavy Industries Ltd.
2.101 M. MINAMI, Y. TOYAMA, S. ABE and T. SENSU, Vibration Analysis of Large Ships Included Higher Mode Vibration. Euromech 122, Paris 1979.
2.102 Y. YAMAMOTO, M. FUJINO, T. FUKASAWA and H. OHTSUBO, Slamming and Whipping of Ships Among Rough Seas. Euromech 122, Paris, Sept. 1979.
2.103 R. E. D. BISHOP, W. G. PRICE and P. K. Y. TAM, On the dynamics of slamming. Trans. RINA 120, 1978, pp. 259-280.
2.104 J. G. LEKKERKERKER, Wave Induced Vibrations of a Ship Hull with Internal Damping. Euromech 122, Paris, Sept. 1979.
2.105 S. G. STIANSEN, Propeller and Wave-Induced Hull Structure Vibrations. SNAME and SSC Ship Vibration Symposium, Oct. 1978, Arlington, Va., U.S.A.
2.106 S. HYLARIDES, Hull Resonance No Explanation of Excessive Vibrations. I.S.P. 21 No. 236, April 1974.
2.107 D. CATLEY and C. NORRIS, Theoretical Prediction of the Vertical Dynamic Response of Ship Structures Using Finite Elements and Correlation with Ship Mobility Measurements. 11th Symposium on Naval Hydrodynamics, 1976.
2.108 W. H. GROTH und H. G. PAYER, Untersuchungen über das Dämpfungsverhalten schiffbaulicher Konstruktionen. Bericht 53/75 FDS Hamburg, 1975.
2.109 I. ANGELOW, Möglichkeiten zur problemorientierten Anwendung der Methode der finiten Elemente für die Berechnung der Schwingungen von Schiffskonstruktionen. Symposium der Technischen Hochschule Varna, 1978.
2.110 I. ANGELOW, Berechnung der freien Querschwingungen des Schiffskörpers mittels einer Kombination der Methode der finiten Elemente und Reduktionsverfahrens. Schiffbau und Schiffahrt, 1, 1977. (In Bulgarian).
2.111 I. A. ANGELOW, Berechnung der erzwungenen Querschwingungen des Schiffskörpers mittels einer Kombination der Methode der finiten Elemente und des Reduktionsverfahrens. Schiffbauforschung 17, 3/4, 1978.
2.112 I. ANGELOW, Berechnung der erzwungenen Querkoeffizienten für vertikale Schiffskörperschwingungen auf der Grundlage von Messergebnissen. Schiffbauforschung 17, 5/6, 1978.
2.113 I. ANGELOW, Calculation of the forced vertical ship vibrations by a combined application of the Finite Element Method and the Method of Partial Responses. Annual report of the Institute for Shipbuilding, Varna 1978. (In Bulgarian).
2.114 V. APOSTOLOV and I. ANGELOW, Free vibrations of a prismatic bar with the shear and the rotational inertia of sections taken into account. Annual report of the Institute for Shipbuilding, Varna 1978. (In Bulgarian).
2.115 I. ANGELOW and V. KIRCHEV, Determination of the ship hull's characteristics to the ship's general free vibrations. Annual Report of the Institute for Shipbuilding, Varna 1975. (In Bulgarian).
2.116 P. C. CHOWDHURY, An alternative to the Normal Mode Method. Computers & Structures, Vol. 5, 1975.
2.117 P. C. CHOWDHURY, The truncated Lanczos algorithm for partial solution of the symmetric eigenproblem. Computers & Structures, Vol. 6, 1976, pp. 439-446.
2.118 B. DUVAL and J. C. PALLARD, Utilisation d'une chaîne de programmes intégrés pour le calcul des structures de navire. Nouveautés Techniques Maritimes, 1976.
2.119 M. D. MILES, On the short-term distribution of the peaks of combined low frequency and springing stresses. SNAME.
2.120 K. OHTAKA, Practical approach for estimation of hull vibration. PRADS-International Symposium on Practical Design in Shipbuilding, Tokyo, Oct. 1977.
2.121 R. E. D. BISHOP and W. G. PRICE, Some observations on linear hydroelasticity of ships. Euromech 122, Symposium Paris, Sept. 1979.
2.122 K. HASHIMOTO, M. FUJINO and S. MOTORA, A study on the wave-induced ship-hull vibration: springing caused by higher-order wave exciting force. Euromech 122 Symposium, Paris, Sept. 1979.
2.123 O. BELIK, R. E. D. BISHOP, W. G. PRICE and J. C. BROWN, A comparison of theoretical and measured symmetric response of a segmented model in regular waves. Euromech 122 Symposium, Paris, Sept. 1979.
2.124 J. WIECKOWSKI, Introduction to dynamics of floating chain systems in discrete description. Euromech 122 Symposium, Paris, Sept. 1979.
2.125 H. SHURI and T. KURIHARA, A Study on the Application of Statistical Energy Analysis to Sound and Vibration Transmission, JKSNA, No. 173, (June '79) (in Japanese) Journal Kansai Soc. Nav. Arch.
2.126 Y. YOKOKURA, Calculation of Vibration Transmission through Large Complicated Structures by Statistical Energy Analysis (Japanese), IHI, Eng. Review, Vol. 18, No. 5, Sept. 1978.

*Chapter 2, section 2.3*

On regional response:

2.127 D. KAVLIE and H. AASJORD, Prediction of Vibration in the Afterbody of Ships. Norwegian Maritime Research, No. 4, 1977.
2.128 S. HYLARIDES and R. VAN DE GRAAF, VLCC deckhouse vibration. Calculations compared with measurements. Monograph Neth. Mar. Inst., M6, July 1976.

2.129 M. MANO, Y. OCHI and K. FUJII, Prevention and Remedy of Ship Vibration. IHI Engineering Review, Vol. 10, No. 3, July 1977.

2.130 M. YAMAKOSHI, Y. MAEDA and T. TCHIBANA, Fundamental Study on the Fore-and-Aft Vibration of Superstructure. Trans. of the West-Japan Society of Naval Architects, No. 54, Aug. 1977.

2.131 G. C. VOLCY et P. MOREL, Vibrations des superstructures des navires. Leurs causes – leurs remèdes. Nouveautés Techniques Maritimes 1976.

2.132 H. H. PAYER and A. WESTRAM, Elastic Foundation of Deckhouses. SNAME, Spring Meeting, Houston, April 1979.

2.133 H. C. PAYER, B. BECKHUSEN und A. WESTRAM, Messtechnische und rechnerische Untersuchung propeller- und maschinenerregter Schwingungen in Aufbauten von Ro-Ro-Schiffen. Bericht Nr. 86/1979, FDS, Hamburg.

2.134 J. LARSEN, Prediction of super-structure vibrations in tankers. Euromech 122 Symposium, Paris, Sept. 1979.

2.135 J. L. ARMAND, P. ORSERO and O. ROBERT, Dynamic Analysis of the Afterbody of a Ship – Towards a Successful Correlation Between Analytical and Experimental Results. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

2.136 T. NAKAMURA, K. KAGAWA, T. HIRAYAMA, K. FUJITA, Y. OMURA and M. ONOUE, The Results of Vibration Test of Stern Part Structure on Twin Screw Container Ship. Mitsubishi Heavy Industries Ltd., Tokyo, Oct. 1977.

On shaft response:

2.137 A. W. VAN BEEK, The vibratory behaviour of a rotating propeller shaft. Part I: Theoretical analysis. Monograph Neth. Mar. Inst., M28, Feb. 1979.

2.138 L. J. WEVERS, The vibratory behaviour of a rotating propeller shaft. Part II: Experimental analysis. Monograph Neth. Mar. Inst., M29, Feb. 1979.

2.139 G. C. VOLCY, M. BAUDIN and P. MOREL, Integrated Treatment of Static and Vibratory Behaviour of Twin-Screw 553,000 dwt Tankers. Trans. RINA, 1978.

2.140 G. C. VOLCY, Interaction and Compatibility Between Machinery and Hull from a Static and Vibratory Point of View. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

2.141 K. OHTAKA and T. NAKAMURA, On the Forced Responce of Propeller Shaft. (In Japanese).

2.142 M. MANO, Hull girder flexural vertical vibration caused by second order unbalanced moment of diesel main engine. Euromech 122 Symposium, Paris, Sept. 1979.

2.143 T. KUCHARSKI, Torsional vibration of the propulsion system in transient state. Euromech 122 Symposium, Paris, Sept. 1979.

2.144 R. KINNS, The deduction of bearing forces in rotating machinery. Euromech 122 Symposium, Paris, Sept. 1979.

2.145 G. H. M. BEEK, A Contribution to Tailshaft Dynamics. Lips.

2.146 S. HYLARIDES, Transverse Vibrations of Ship's Propulsion Systems. Part I: Theoretical Analysis. Report No. 197 M, Neth. Ship Research Centre TNO, Delft, Oct. 1974.

2.147 L. VASSILOPOULOS and R. BRADSHAW, Couples Transverse Shaft Vibrations of Modern Ships. SNAME, New England Section.

2.148 L. VASSILOPOULOS, The Influence of Propeller Mean Loads on Propulsion Shaft Alignment. SNAME Propeller '78 Symposium, Virginia Beach, Va., U.S.A., May 1978.

2.149 R. WERELDSMA, Experimentelle Versuchsanlage für Schraubenwellendynamik in Querrichtung. Jahrbuch der STG, Hamburg, 1978.

2.150 L. J. WEVERS, Transverse Vibrations of Ship's Propulsion Systems. Part II: Experimental Analysis. Report No. 203 M, Neth. Ship Research Centre TNO, Delft, Dec. 1974.

2.151 D. KÖSTER, H. G. PAYER und A. WESTRAM, Untersuchungen über erzwungene Wellenbiegeschwingungen unter Berücksichtigung der Dämpfung. Bericht Nr. 73/1977, FDS Hamburg.

2.152 G. ANDERSSON, D. KÖSTER und H. PAYER, Untersuchung von Wellenbiegeschwingungen grosser, schneller Zweischraubenschiffe. Bericht Nr. 44/1974, FDS Hamburg.

2.153 S. HYLARIDES, Parameter Investigation in Transverse Shaft Vibrations. Report No. 1113-3-ST, NSMB Wageningen.

2.154 G. GERCHEV and L. BELCHEV, Torsional Vibration of the Ship Shaft Line with a Joint Having Non-Linear Elastic Characteristics. Annual Report Bulgarian Ship Research Institute, Varna, 1977.

2.155 P. VANGELOV, On the Approximate Assessment of the Axis Yield of the Cranks of Internal Combustion Engine Crankshafts. Report Bulgarian Ship Research Institute, Varna, 1977.

2.156 C. ARCHER and D. K. MARTYN, Static and Dynamic Alignment. The Institute of Marine Engineers, Conference on Operational Aspects of Propulsion Shafting Systems, May 1979, London.

2.157 W. MCCLIMONT and D. MCKINLAY, Review of Shafting Problems. The Institute of Marine Engineers, Conference on Operational Aspects of Propulsion Shafting Systems, May 1979, London.

2.158 L. VASSILOPOULOS, Payload and Propeller Constraints in Optimum Shaft. Alignment Selection Problems. The Institute of Marine Engineers, Conference on Operational Aspects of Propulsion Shafting Systems, London, May 1979.

2.159 H. SCHWANECKE, Hydrodynamic Stiffness and Damping of Thrust Bearings in Ships. The Institute of Marine Engineers, Conference on Operational Aspects of Propulsion Shafting Systems, London, May 1979.

2.160 J. C. DAIDOLA and V. W. JOVINO, The effect of hull girder stiffness on propulsion machinery alignment. Euromech 122 Symposium, Paris, Sept. 1979.

2.161 M. FUKUTOME, K. FUJII, S. KATO, H. YASHIMA and M. IWAMA, Machinery Vibration in the Engine Room of Motor Ships (Japanese) IHI Eng. Review, Vol. 16, No. 1, Jan. 1976.

2.162 K. ASOU, Vibration Characteristics of Marine Boilers (Japanese) IHI Eng. Review, Vol. 16, No. 3, March 1976.

2.163 Y. OCHI and K. TANIDA, On the Prevention of Vibration of Double Bottom in Engine Room (Japanese) Trans. of the West-Japan Society of Naval Architects, No. 52, Aug. 1976.

2.164 Y. OCHI and K. TANIDA, Lateral Vibration of Line Shafting and Bossing of a Single Screw Container Ship (Japanese) Trans. of the West-Japan Society of Naval Architects, No. 52, Aug. 1976.

2.165 Y. OCHI, J. TANIDA and R. FUJINO, Prevention of Engine Room Vibration, 1st Report – An Engine Room Double Bottom – (Japanese) IHI Eng. Review, Vol. 16, No. 6, Nov. 1976.

2.166 T. NAGANO, H. HIRAI, H. YASHIMA, S. KUMAZAKI and H. KIMURA, Vibration of After Peak Tank Structure (Japanese) Jour. of Kansai Society of Naval Architects, No. 161, 1976.

2.167 K. TANIDA and Y. OCHI, Prevention of Engine Room Vibration, 2nd Report – Transverse Vibration of Diesel

Engine - (Japanese) IHI Eng. Review, Vol. 17, No. 1, Jan. 1977.

2.168 DIESEL ENGINE DEPARTMENT, Effect of the Hydraulic Axial Vibration Damper on the Crankshaft Axial Vibration of the IHI-SULZER Marine Main Diesel Engine (Japanese) IHI Eng. Review, Vol. 17, No. 2, March 1977.

2.169 M. MANO, Y. OCHI and K. FUJII, Prevention and Remedy of Ship Vibration (English) IHI Eng. Review, Vol. 10, No. 3, July 1977.

2.170 Y. OCHI and K. TANIDA, Lateral Vibration of Propeller Shaft and Bossing (Japanese) IHI Eng. Review Vol. 17, No. 3, May 1977.

2.171 K. FUJII, Vibration Reduction by the phase Adjustment between Thrust Fluctuation and Longitudinal Excitating Force of Diesel Engine (Japanese) Bull. of the Society of Naval Architects of Japan, No. 580, Oct. 1977.

2.172 Y. OCHI, K. TANIDA and R. FUJINO, Prevention of Engine Room Vibration - An Engine Room Double Bottom - (English) PRADS Tokyo, Oct. 1977.

2.173 M. MANO, Hull Girder Flexural Vertical Vibration Caused by 2nd Order Unbalanced Moment of Diesel Main Engine (English) EUROMECH Symposium on Numerical Analysis of the Dynamics of Ship Structures, Sept. 1979.

*Chapter 2, section 2.4*

On local response:

2.174 R. HAMMER und R. POSTL, Angenäherte Berechnung fremderregter Schwingungen orthogonal verrippter Platten. Schiffbauforschung 16, 5/6, 1977.

2.175 H.-J. SCHLÜTER, Berechnung der Eigenschwingungen orthogonal verrippter Rechteckplatten bei beliebigen Randbedingungen einschliesslich elastisch gelagerter und elastisch eingespannter Ränder sowie Randmassenträgheiten, elastischer Stützen, Punktmassenträgheiten und elastisch befestigter starrer Körper. Schiffbauforschung 16, 3/4, 1977.

2.176 H.-J. SCHLÜTER, Die Ermittlung von Eigenfrequenzen und Eigenschwingungsformen der orthogonal verrippter Rechteckplatte bei beliebigen Kombinationen eingespannter, frei-drehbar gelagerter und freier Ränder. Schiffbauforschung 15, 5/6, 1976.

2.177 H. PFAU, Eigenfrequenzen von Balken und Platten mit veränderlicher Steifigkeit. Schiffbauforschung 18, 3/4, 1979.

2.178 H. BÖTTCHER, E. LAREK und H. PFAU, Die numerische Berechnung der Eigenschwingungen isotroper flacher Zylinderschalen unter Verwendung des Differenzenverfahrens. Schiffbauforschung 16, 1/2, 1977.

2.179 H. PFAU und H.-J. BATHKE, Zur Berechnung der Eigenschwingungen flacher isotroper Zylinderschalen unter Verwendung des Differenzenverfahrens. Schiffbauforschung 15, 3/4, 1976.

2.180 A. ROSCHER, Brechnung fremderregter Schwingungen an dünnwandigen Schalen auf der Grundlage eines Finite-Element-Modells. Schiffbauforschung 18, 1/2, 1979.

2.181 N. FL. MADSEN, Vibrations of Orthogonally Stiffened Panels, Journal of Ship Research, Vol. 22, No. 2, June 1978, pp. 100-109.

2.182 SPAN, a Computer Program for Static and Dynamic Analysis of Stiffened Plates and Grillages. Report No. NCRE/R630 (Item A2), Naval Construction Research Establishment Dunfermline, Feb. 1976.

2.183 KL.-D. MEINKE, Experimentelle Untersuchungen zu lokalen Schwingungen des Schiffskörpers. Veröffentlichung Weiterbildungsseminares "Schiffsschwingungen". (Sonderdrück der W.-Pieck-Universität Rostock).

2.184 G. SCHLOTTMANN, Schwingungsberechnungen mit der Methode der finiten Elemente. Proceedings of the Third Seminar on Finite Element Method and Variational Methods. Plzen/CSSR, Oct. 4.-7. 1977, part III, pp. 557-570.

2.185 G. SCHLOTTMANN und K.-P. SCHMITZ, Zur Berechnung des Eigenschwingungsverhaltens von Aufbautendecks. Schiffbauforschung 17, (1968), 5/6, 222-228.

2.186 K.-P. SCHMITZ und G. SCHLOTTMANN, Einige Zusammenhänge zwischen Leichtbau und Schwingungserscheinungen in Aufbautendecks. Veröffentlichungen zum Schiffstechnischen Symposium an der Wilhelm-Pieck-Universität Rostock, 20.-22.9.1978 in Rostock.

2.187 G. SCHLOTTMANN und K.-P. SCHMITZ, Lokale Schwingungen von Aufbautendecks. Veröffentlichungen zum Seminar "Schiffsschwingungen" der Wilhelm-Pieck-Universität und des Instituts für Schiffbau Rostock, 6.-10. 11.1978 in Friedrichswalde.

2.188 K.-P. SCHMITZ und G. SCHLOTTMANN, Globale Heck-Aufbautenschwingungen. Veröffentlichungen zum Seminar "Schiffsschwingungen" der Wilhelm-Pieck-Universität und des Institutes für Schiffbau Rostock, 6.-10.11.1978.

2.189 R. POSTL, Erscheinungen mechanischer Schwingungen auf Schiffen. Phenomenons of mechanical vibrations on ships. Proceedings Seminar "Schiffsschwingungen" der Wilhelm-Pieck-Universität Rostock und des Instituts für Schiffbau Rostock, 6.-10.11.1978 in Friedrichswalde.

2.190 R. POSTL, Maschinendynamische Erregungen auf Schiffen und Erregungen durch den Seegang. Proceedings Seminar Schiffsschwingungen der Wilhelm-Pieck-Universität Rostock und des Instituts für Schiffbau Rostock, 6.-10.11.1978 in Friedrichswalde.

2.191 H.-J. SCHLÜTER, Berechnung der Eigenschwingungen orthogonal verrippter Rechteckplatten bei beliebigen Randbedingungen einschliesslich elastisch gelagerter und elastisch eingespannter Ränder sowie Randmassenträgheiten, elastischer Stützen, Punktmassenträgheiten und elastisch befestigter starrer Körper. Schiffbauforschung 16, (1977), H. 3/4, S. 141-147.

2.192 H.-J. SCHLÜTER, Die Berechnung von Eigenschwingungen orthogonal verrippter Platten mit Hilfe der Energiemethode. Zeitschrift der Wilhelm-Pieck-Universität Rostock 1978.

2.193 H.-J. SCHLÜTER, Berechnunge der Eigenschwingungen von Flächentragwerken. Veröffentlichungen zum Seminar "Schiffsschwingungen" der Wilhelm-Pieck-Universität Rostock und des Instituts für Schiffbau Rostock, 6.-10.11.1978 in Friedrichswalde.

*Chapter 3*

On criteria and general considerations:

3.01 E. F. NOONAN, An Assessment of Current Shipboard Vibration Technology, SNAME, 1975.

3.02 F. E. REED, Acceptable Levels of Vibration on Ships. Marine Technology, April 1973.

3.03 W. GESSNER, Problem der Schaffung von Schwingungsnormen. DDR-Schiffbau-Information Rostock, 8, (1976), 13/14.

3.04 See (4.42).

3.05 K. KAUBE und H. G. PAYER, Zulässige Schwingungen an Bord von Schiffen. Germ. Lloyd Hamburg.

3.06 J. ASMUSSEN und H. G. PAYER, Schwingungstechnische Grenzen für Hauptmotoren Geringer Zylinderzahlen. Bericht Nr. 88/1979, FDS Hamburg. (See 1.76).

3.07 E. F. NOONAN and S. FELDMAN, State of the Art for Shipboard Vibration and Noise Control. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

3.08 R. MCFARLAND and D. LINDQUIST, Vibration from a Ship Owner's Standpoint. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

3.09 N. M. MANIAR and J. C. DAIDOLA, The Considerations of Vibrations and Noise at the Preliminary and Contract Levels of Ship Design. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

3.10 R. D. GLASFELD and D. C. MACMILLAN, Vibration from a Shipbuilder's Point of View. SNAME and SSC Ship Vibration Symposium, Arlington Va., U.S.A., Oct. 1978.

3.11 R. F. SCHAMANN, Noise and Vibration as Viewed by a Maritime Union. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

3.12 F. E. REED and O. H. BURNSIDE, Computer Techniques for Use in Ship Hull Vibration Analysis and Design. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

3.13 J. J. KAPPEL, An Owner's View on Propeller Induced Vibrations. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 1.

On vibration standard:

3.14 I.S.O. Draft Proposal. Doc. No. 6954, Revised Sept. 1979.

*Chapter 4, section 4.1.*

On vibration damping, isolation and acoustics:

4.01 W. OJAK, O potrzebie i skuteczncsci posadowien elastycznych na statkach. Institutu Monskiego, Gdansk, Poland. (In Polish).

4.02 L. PALM, K.-P. SCHMITZ, D. ZANDER, H. BLOSSFELD und H. HOPPE, Aktive Bekämpfung von Schiffskörperschwingungen auf einem 10400-t-Frachtschiff. Seewirtschaft 9, 7/1977.

4.03 M. TZ. TZENKOV, Experimental and theoretical investigation of ship hydropneumatic dampers. Thesis of dissertation, Shipbuilding Institute Leningrad, 1977.

4.04 N. KURATA, H. OHSHIMA, K. YAMAZAKI, S. HASHIGUCHI, N. SAKATA, Y. SHIMURA, T. MAEDA, Y. MIZOGUCHI and K. MATSUMOTO, Vibration Control Apparatus Using Active Force Generator for Ship, The Hitachi Zosen Technical Review, Vol. 39, No. 4.

4.05 M. KUNIEDA, M. MANO, K. FUJII and Y. OKADA, Isolation of Propeller Thrust Fluctuation to Ship Structures by Air Springs (English) IHI Eng. Review, Vol. 10, No. 1, jan. 1977.

4.06 T. TEN WOLDE and A. DE BRUIJN, A new method for the measurement of the acoustical source strength of cavitating ship propellers. I.S.P.

4.07 J. W. VERHEIJ, Experiments on acoustic modelling of machinery excitation. Monograph Neth. Mar. Inst., M17, April 1977.

4.08 J. v. D. KOOIJ and A. G. P. VERSMISSEN, Noise and hull pressure measurements in the depressurized towing tank of the Netherlands Ship Model Basin. NSMB Wageningen, April 1978.

4.09 A. DE BRUIJN, The determination of the acoustical source strength of propellers of two merchant vessels. Monograph Neth. Mar. Inst., M16, April 1977.

4.10 H. SCHWANECKE, Der derzeitige Stand der Kenntnisse und noch offene Probleme über den Körperschall im Hinblick auf die konstruktive Gestaltung des Schiffskörpers. Schiff und Hafen/Kommandobrücke, heft 2/1978, 30. Jahrg.

4.11 G. WARD and A. HOYLAND, Ship Design and Noise Levels. North-East Coast Institution of Engineers and Shipbuilders, Newcastle upon Tyne, March 1979.

4.12 A. DE BRUIJN, Acoustic source strength measurements of propeller cavitation for two cargo motor vessels. Monograph Neth. Mar. Inst., M24, Oct. 1978.

4.13 A. DE BRUIJN and A. G. P. VERSMISSEN, Model experiments for the determination of the acoustic source strength of ship propeller cavitation of s.s. "Abel Tasman". Monograph Net. Mar. Inst., M26, Oct. 1978.

4.14 J. BUITEN, M. J. A. M. DE REGT and J. W. VERHEIJ, Sound transmissions into a ship's cabin built of steel plate sandwich panels. Monograph Neth. Mar. Inst., M26, Oct. 1978.

4.15 J. BUITEN and H. AARTSEN, Investigation into noise exposure of engine room personnel aboard m.s. "Trident Amsterdam". Monograph Neth. Mar. Inst., M27, Feb. 1979.

4.16 D. COSSÉ, Les dosimètres de bruit du Bureau Veritas. Bulletin Technique du Bureau Veritas, Dec. 1976.

4.17 J.-P. FOURNET, Quelques réflexions sur l'isolation acoustique aux bruits aériens entre locaux. Bulletin Technique du Bureau Veritas, febr. 1975.

4.18 H. MARKWARDT, Kontrolle und Normierung der Schallpegel auf Schiffen. DDR-Schiffbau-Information Rostock 9, 13/14, 1977.

4.19 D. VELKOV, A mathematical model and a method of studying the acoustic vibrations of ship hull structures. Annual Report of the Shipbuilding Institute Varna, 1978 (in Bulgarian).

4.20 G. FINJECOV, On some specific features of noise radiation from ship hull structures. Annual Report of the Shipbuilding Institute Varna, 1977 (in Bulgarian).

4.21 A. C. NILSSON, Noise Prediction and Prevention in Ships. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

4.22 F. A. THOMA, OSHA Noise Levels and the Marine Industry. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

*Chapter 4, section 4.2*

On statistical methods:

4.23 K. O. HOLDEN, Excitation forces and afterbody vibrations induced by marine propeller blade cavitation. Norwegian Maritime Research No. 1, 1979.

4.24 S. HYLARIDES, Study into statistical information on propeller-induced ship vibrations. Report No. 02845-1-ST, NSMB Wageningen, 1978.

4.25 J. HOLTROP, Statistical analysis of hull-pressure tests. Report No. W11006-16-VT, NSMB Wageningen, June 1978.

4.26 J. HOLTROP, Estimation of Propeller Induced Vibratory Hull Forces at the Design Stage of a Ship. RINA Symposium on Propeller Induced Ship Vibrations, London, Dec. 1979. Paper No. 11.

4.27 R. RUTHERFORD, Aft end shaping to limit vibration. North East Coast Inst. of Engineers and Shipbuilders, 1979.

4.28 C. E. J. LEENAARS and P. E. FORBES, An Approach to Vibration Problems at the Design Stage. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 17.

4.29 A. FITZSIMMONS, Cavitation Induced Hull Pressures: A Comparison of Analytical Results, Ship and Model Measurements. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 9.

Full coverage and non-specific:

4.30 O. H. BURNSIDE, D. D. KANA and F. E. REED, Bibliography for the Study of Propeller-Induced Vibration in Hull Structural Elements. Report SSC-281, 1978.

4.31 W. S. VORUS, S. G. STIANSEN and R. H. BERTZ, Correlations of propeller induced forces and structural vibratory response of the m.v. "Roger Blough". Dept. of Nav. Arch. and Mar. Eng., College of Engineering, The University of Michigan, Report No. 193, Oct. 1977.

4.32 C. CAMISETTI, G. SANI and Z. ZADARICCHIO, Vibratory Behaviour of Containerships: Correlation between Measurements and Calculations. Euromech 122 Symposium, Paris, Sept. 1979.

4.33 C. F. LENNING, Vibration Analysis of the Norwegian Coast Guard Vessel. Euromech 122 Symposium, Paris, Sept. 1979.

4.34 K. TAKEKUMA, Vibration Problem With a Class of Cargo Liner and the Solution from Fitting a Fin. RINA Symposium on Propeller Induced Ship Vibration, London, Dec. 1979. Paper No. 18.

4.35 W. OJAK, Kontrola i zasady odbiori statkow pod katem drgan. Institutu Morskiego Gdansk, 1978.

4.36 W. GESSNER, Richtlinie für die Ausarbeitung von schwingungstechnischen Projekten für Seeschiffe. DDR-Schiffbau-Information Rostock 10, 6, 1978.

4.37 W. GESSNER, K.-P. SCHMITZ, E. LANGECKER, L. PALM, D. LORENZ und O. KOHLEN, Schwingungsuntersuchungen zur Schiffsoptimierung. DDR-Schiffbau-Information Rostock 9, 13/14, 1977.

4.38 C. NATH, H. G. PAYER and E. A. PLESS, Calculations, measurements and resulting remedies for vibration problems on Ro/Ro ships. Symposium on Practical Experiences with Flow-Induced Vibrations. Session G: Ship Structures. Karlsruhe, Germany, Sept. 3–6, 1979.

4.39 E. A. PLESS, Vibration and noise problems on board of ships. 2. Technisches Kolloquium des Germanischen Lloyd, Athen, 13. Okt. 1978.

4.40 A. LEONIEC and W. OJAK, An approach to vibration problems on Ro-Ro ships. Norwegian-Polish Seminar on the Modern Ship Vibration Problems, Gdansk, 23–24 Oct. 1978.

4.41 W. OJAK, Vibration problems on modern ships due to propeller excitations. 4th Italian-Polish Seminar on the Ship Structures and Hydrodynamics, Genova, June 1979.

4.42 Recommendations en vue de limiter les effets des vibrations à bord des navires. Bureau Veritas 1978. Note d'information NI 138 A-RD3, Juin 1979.

4.43 T. SØNTVEDT and others, Report of Committee II.4: Steady-State Dynamic Loading and Response. ISSC 1979, issued by IRCN, Paris.

4.44 Machinery Hull Interaction – Vibrations. Bureau Veritas, Head Office, Paris.

4.45 G. C. VOLCY, M. BAUDIN and P. MOREL, L'amortissement dans les vibrations des navires. Nouveautés Techniques Maritimes, 1978.

4.46 Ships, the Sea and the Computer. Bureau Veritas, Head Office, Paris.

4.47 J.-M. PLANEIX, M. HUTHER, J.-J. TOURNIER and B. DUVAL, Development of an integrated computerized process for the classification of ships. Computer Applications in the Automation of Shipyard Operation and Ship Design II, 1976.

4.48 J. PACZESNIAK, Draft destined to the "Rules for the classification and construction of sea-going ships". Newly proposed version for replacement the chapter 28 in part II "Hull" entitled: Recommendations as to prediction and prevention of vibration on board ships. Polski Rejestr Statkow, Gdansk, Sept. 1978.

4.49 O. H. SOLUMSMOEN, Ship vibration. Experience from service measurements. Det norske Veritas, Publ. No. 96, Jan. 1977.

4.50 F. E. REED and O. H. BURNSIDE, Computer Techniques for Use in Ship Hull, Vibration Analysis and Design. SNAME and SSC Ship Vibration Symposium, Arlington, Va., U.S.A., Oct. 1978.

4.51 D. HOFFMAN, C. C. HSIUNG and T. E. ZIELINSKI, Wave Load Distributions on Large Ships. SNAME, 1975.

4.52 E. V. LEWIS and R. B. ZUBALY, Dynamic Loadings Due to Waves and Ship Motions. SNAME, 1975.

# PUBLICATIONS OF THE NETHERLANDS MARITIME INSTITUTE

**Monographs**

M 1 Fleetsimulation with conventional ships and seagoing tug/barge combinations, Robert W. Bos, 1976.
M 2 Ship vibration analysis by finite element technique. Part III: Damping in ship hull vibrations, S. Hylarides, 1976.
M 3 The impact of Comecon maritime policy on western shipping, Jac. de Jong, 1976.
M 4 Influence of hull inclination and hull-duct clearance on performance, cavitation and hull excitation of a ducted propeller, Part I, W. van Gent and J. van der Kooij, 1976.
M 5 Damped hull vibrations of a cargo vessel, calculations and measurements, S. Hylarides, 1976.
M 6 VLCC deckhouse vibration, Calculations compared with measurements, S. Hylarides and R. van de Graaf, 1976.
M 7 Finite element ship hull vibration analysis compared with full scale measurements, T. H. Oei, 1976.
M 8 Investigations about noise abatement measures in way of ship's accommodation by means of two laboratory facilities, J. Buiten and H. Aartsen, 1976.
M 9 The Rhine-Main-Danube connection and its economical implications for Europe, Jac. de Jong, 1976.
M 10 The optimum routeing of pipes in a ship's engine room, C. van der Tak and J. J. G. Koopmans, 1977.
M 11 Full-scale hull pressure measurements on the afterbody of the third-generation containership s.s. "Nedlloyd Delft", R. A. P. J. Schulze, 1977.
M 12 Cavitation phenomena and propeller-induced hull pressure fluctuations of a third-generation containership, A. Jonk and J. van der Kooij, 1977.
M 13 Hull vibration measurements carried out on board the third-generation containership s.s. "Nedlloyd Delft", R. A. P. J. Schulze, 1977.
M 14 Hull vibrations third-generation containership, S. Hylarides, 1977.
M 15 Influence of hull inclination and hull-duct clearance on performance, cavitation and hull excitation of a ducted propeller, Part II, J. van der Kooij and W. van den Berg, 1977.
M 16 The determination of the acoustical source strength of propellers of two merchant vessels. A. de Bruijn, 1977.
M 17 Experiments on acoustic modelling of machinery excitation, J. W. Verheij, 1977.
M 18 The effect of a pram-type aftbody shape on performance, cavitation and vibration characteristics of twin-screw dredgers. W. van den Berg and J. van der Kooij, 1977.
M 19 Investigations into the effect of model scale on the performance of two geosim ship models, Part I: Flow behaviour and performance in calm water, A. Jonk and J. van de Beek, 1977.
M 20 Investigations into the effect of model scale on the performance of two geosim ship models, Part II: Behaviour and performance in waves, M. F. van Sluijs and R. J. Dommershuijzen, 1977.
M 21 A Tale of Eight Seaports. Jac. de Jong, 1977.
M 22 An investigation into the difference between nominal and effective wakes for two twin-screw ships, M. Hoekstra, 1977.
M 23 Residue calculation method for chemical tankers, H. J. A. Schuurmans and J. G. M. Schilder, 1978.
M 24 Acoustic source strength measurements of a ship propeller cavitation for two cargo motor vessels, A. DE BRUIJN, 1978.
M 25 Model experiments for the determination of the acoustic source strength of ship propeller cavitation of s.s. "Abel Tasman", A. de Bruijn and A. G. P. Versmissen, 1978.
M 26 Sound transmission into a ship's cabin built of steel plate sand wich panels, J. Buiten, M. J. A. M. de Regt and J. W. Verheij, 1979.
M 27 Investigation into noise exposure of engine room personnel aboard m.s. "Trident Amsterdam", J. Buiten and H. Aartsen, 1979.
M 28 The vibratory behaviour of a rotating propeller shaft Part I, Theoretical analysis, A. W. van Beek.
M 29 The vibratory behaviour of a rotating propeller shaft, Part II, Experimental analysis, L. J. Wevers, 1979.
M 30 The effect of a floating floor as an acoustical measure on board a ship, J. Buiten and M. J. A. M. de Regt, 1979.
M 31 Emulsification of chemical tanker slops and dimensioning of slop's discharge ports, H. J. A. Schuurmans, C. A. M. Oudshoorn, A. P. Mahieu, F. H. J. Bukkems and H. van der Poel, 1979.
M 32 Sound transmission to a ship's cabin constructed with fibre-reinforced calcium silicate panels, J. Buiten and M. J. A. M. de Regt, 1979.
M 33 Homogenization of chemical tanker slops, H. J. A. Schuurmans, F. H. J. Bukkems and J. G. M. Schilder, 1979
M 34 Chemical tanker cleaning by ventilation, H. J. A. Schuurmans and J. G. M. Schilder, 1979.
M 35 Prewash procedures for chemical tankers, H. J. A. Schuurmans and J. G. M. Schilder, 1979.
M 36 Physical and chemical properties of chemicals shipped in bulk, D. M. Brouwer, H. J. A. Schuurmans, J. G. M. Schilder and W. Dannenberg, 1979.
M 37 Investigation into the effect of different afterbody lines of high-powered single screw ships on propeller-generated hull-pressure fluctuations, A. Jonk and J. van der Kooij, 1979.

**Reports**

R 69 Flame cutting and one-sided mechanised MAG welding, in the vertical position, M. P. Sipkes, 1978 (in Dutch).

**Published by the Netherlands Maritime Institute**
**19, Hofplein p.o. box 1555**
**3000 BN Rotterdam, the Netherlands**
**telephone (010) 114768**
**telex: 27067, cables: nemarin rotterdam**

**Printed by Meinema bv, Delft**