THE PRESENT STATE OF SHIP THEORY

GEORGE P. WEINBLUM

INTRODUCTION

“The ship is a vehicle whose weight is supported by forces created in water.” This definition is no more exhaustive after the hovercraft (GEM) has appeared; frequently (as will be done here), the latter is excluded from the family of ships, which, unfortunately, does not settle all the scientific questions involved.

“The investigation of properties of the ship which are fundamental from the standpoint of mechanics is the subject of Ship Theory.” (In a narrower sense, however, only those problems belong to ship theory in which the hull can be considered as a rigid body.) While we were earlier satisfied by this approximate statement, we must now answer first the question put recently by a prominent colleague: “Is there such a science as ship theory?” The increasing weight of general disciplines, primarily hydrodynamics, seems to displace the usefulness of particular problems posed by the engineering profession as yardsticks of our subject. Thus, for example, the concept “Ship (or Naval) Hydrodynamics” has slightly obscured our dignified term “Ship Theory.” Actually, the latter being more general, retains its full meaning. The presentation used in most books is advisable; here a section on ship hydrodynamics is included.

Ship hydrodynamics is displacing aerodynamics as the principal inspiration in the field of research on ideal, as well as viscous, incompressible flows.

A new comprehensive concept — hydroelasticity — tends to eliminate the borderline between ship theory and “strength of ships,” which already was bridged by the theory of ship vibrations.

In general, an increasing number of problems in ship design (and operation) now become susceptible to scientific treatment, thus widening the scope of our subject.

There are perhaps few fields in the engineering sciences where the wide use of computers has been so decisive. Complicated solutions, characteristic of our subject, are now readily evaluated, and there is no longer a psychological barrier against developing and applying more exact or comprehensive methods which more closely approximate “reality.” This is a necessary prerequisite for a general use of scientific methods in naval architecture.

Since most ships in present use belong to the displacement class our survey will be devoted primarily to problems connected with such vessels. Scientific work dealing with hydrodynamic craft will be referred to when necessary.

Advanced ideas concerning new types of ships are currently suggested by economic and still more by military considerations. The application of atomic power has stimulated research in many fields of ship theory.

The close relations between oceanography and ship theory will be intensified by a new scientific and technological activity—ocean engineering, of which research submarines are representative.

Finally, without going into detail, we emphasize the importance of ship aerodynamics as a branch of our subject which includes the theory of sailing and general problems caused by wind forces. Although a classic topic in ship theory, it is treated as a side issue here.

SHIP GEOMETRY AND HYDROSTATICS; BUOYANCY AND STABILITY

The determination of the hull form is increasingly based upon analytical (and numerical) methods,
rather than graphical procedures. This development is promoted by

1. theoretical considerations and
2. by practical requirements, i.e. the desire to eliminate the mold loft and to compute the hull ordinates with the accuracy needed for construction.

In theoretical considerations, "exact" representations of ship forms are especially useful in research on wave resistance and ship oscillations in a seaway; pertinent methods are based on (a) a synthetic construction of formulas for the surface from given characteristic form parameters, or (b) on approximating empirical lines by the least squares method. Polynomials are most suitable for these methods since (via spline curves) they are a language understood by ship artisans.

As far as practical requirements go, practice so far prefers procedures which depart from a given empirical set of lines and uses interpolation formulas in a specially adapted form (again based on spline curves).

Our subject is now an important phase of ship theory — ship geometry, a designation used earlier for special investigations on static stability. We have criticized the peculiar use of nomenclature in the field discussed and have proposed the term "righting couple" of roll and trim (reserving the concept of stability for our investigation of the state of equilibrium). The study of extraneous forces causing ships to heel (wind, centrifugal forces, etc.) is now intensified—a necessary prerequisite for standardizing minimum values of the transverse stability parameter. Obviously, the static concept is in many respects inadequate and is being supplemented by considerations based on ship behavior at sea. Nonetheless, recent systematic evaluations of static stability in a damaged state are a valuable contribution. Progress has been achieved in the field of ship subdivision by applying probability theory to problems of ship damage.

SHIP HYDRODYNAMICS

A great and increasing inheritance from classical hydrodynamics and aerodynamics belongs to this chapter; the more specific problems only can be touched upon. From scientific as well as practical considerations we begin with the study of bodies moving in an unbounded medium ("deeply submerged" bodies). More general body forms have been generated by singularities located in a uniform stream by distributing them over the center plane or skeleton surfaces. Still more conspicuous is the progress of the inverse method—the determination of generating singularities for a given body fixed in a uniform or nonuniform flow field. A routine computer procedure has been developed for solutions of the integral equation which determines surface singularities distributed over the hull. The potential flow has been calculated for several "double models" of actual ship forms (the "double model technique" gains in value as a research tool). Similar efforts have been made in the field of real fluids (although still more effort has been made outside this field), and promising results attained in three-dimensional boundary-layer theory. Turbulence is as before a stumbling block. Refined experimental methods have been introduced. Nonetheless, important information on forces experienced by bodies moving in real fluid is lacking.

Obviously, the study of free surface effects is the most essential and conspicuous part of ship hydrodynamics. There is a comprehensive and creative synopsis of the general theory of water waves by Stoker (22) and Wehausen (23). Theories of the ir-regular seaway have been developed and have exerted a decisive influence on the treatment of seaworthiness and ship behavior problems. The theory of body motions close to (or at) an interface has progressed. So far linearized theories dominate the field but attempts are being made to handle second order approximations. Only tentative results so far have been obtained by considering the influence of viscosity on free surface effects.

The study of hydrodynamic impacts experienced by bodies hitting the free surface was originated by narrow applications in seaplane design; it now gains momentum in various fields of applied hydrodynamics. Although fundamental results have been reached earlier, two new solutions of basic character may be quoted:

1. the case of impinging free jets and
2. the consideration of elastic properties of the striking body.

We may pass briefly over the progress made in cavitation studies, especially investigations on the supercavitating state which has led to fundamental new auspices in applications, since we assume that this important subject will be adequately dealt with elsewhere in this volume.

RESISTANCE

Resistance is at present perhaps the most popular subject in ship theory both for scientific and practical reasons. From resistance studies come the strongest scientific impulses for developing new