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Aerodynamics of Air Cushion Vehicles

Some Fluid Dynamic Aspects of ACV

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1. Introduction

In the early days of the ACV industry, the design of marine craft was often based on the static characteristics of the air cushion system and the requirement for a high craft performance in calm water conditions which, it was hoped, would result in acceptable performance in waves.

The static characteristics and calm water drag became important at this time, as they were relatively amenable to theoretical analysis and experimental work on models. Design methods were often empirical and tentatively based on test data from models and the early full scale prototype craft.

The dynamic aspects of craft received scant attention in the design process, as there was little basic knowledge or understanding of the subject. It was hoped perhaps that the response and performance over waves would be better than other forms of marine craft due to the favourable suspension properties expected of the air cushion.

Whilst this expectation has been realised in general terms, it became apparent, as commercial operations increased, that response and performance, even in short waves, required improvement. Specific power levels were high and these had an adverse effect on range as well as on first costs and operating costs.

The implications of the fact that marine ACV hardly ever operate in steady conditions has been recognised, and in recent years, an increasing R and D effort has been made by industry and research establishments in countries concerned with ACV, to gain a fundamental understanding of the mechanisms and effects of dynamic conditions on ACV components and overall craft characteristics.

Complications often arise when the effect of the ever-changing environment is taken into account in simple analysis of many dynamic problems. Consequently, representative design methods are difficult to establish. These methods are important in the process of arriving at the design compromises which dictate the technical basis of craft from the project stage onwards.

Another general problem which has arisen with ACV is the question of scaling from models to man carrying craft and in further extrapolation to larger sizes of craft.

Here, the problems revolve around the demands of the scaling laws for the different structures and fluids which are involved in ACV design and operation.

It is not possible to satisfy simultaneously all the scaling laws involved but progress has been made in identifying the important non-dimensional numbers which govern the effective scaling of ACV and in deriving new test techniques.

This lecture will discuss some of the recent work which has been done on dynamic and scaling problems.

2. The Air Cushion System in Dynamic Conditions

The air cushion system of a marine hovercraft is essentially a dynamic device which can be understood most easily by dividing the whole system into components. The simplest air cushion system (Fig.1) contains the following components in series:-

1. An air intake
2. A fan rotor
3. A rotor outlet that may be either a volute or a plenum chamber
4. A flexible loop or bag
5. An air cushion surrounded by a skirt

The characteristics of the last two components are dependent on their flexible boundaries. They are therefore aeroelastic springs rather than purely aerodynamic ones. Each component can then be analysed and tested with various boundary conditions representing input and output. These boundary conditions are then the transfer functions and feedbacks connecting the components together. When viewed in this way the various parts can then be matched together under dynamic conditions to obtain a complete system with the desired dynamic characteristics.

Some features of two of the components will be described to show how their influence on each other can be determined.

Centrifugal fans are commonly used on hovercraft and have very high static efficiencies. It may be legitimately asked how any further research on these fans can be justified. The answer is that these high efficiencies are obtained at, or close to, one design flow rate, but in practice the flow rates fluctuate considerably when the craft is running over a sea. Such fluctuations could lead to stalling of the fan blades which in turn cause undesirable variations of outlet pressure.

The design of rotor blades for a single design condition need not be sophisticated. The inlet and outlet angles of the air flow can be determined by very simple theory.