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Ship Model Wake Analysis by Means of PIV in Large Circulating Water Channel

F. Di Felice and M. Felli
INSEAN (Italian Ship Model Basin), Rome, Italy

F. De Gregorio
CIRA (Italian Aerospace Research Centre), Capua, Italy

ABSTRACT

The survey of a ship model's wake is a typical step in the hydrodynamic design of a conventional and unconventional hull. Today, the adoption of Particle Image Velocimetry for this kind of applications has become feasible and allows us to obtain a detailed and reliable picture of the flow field, in particular for turbulent and unsteady features. At the INSEAN Circulating Water Channel, such a technique is applied to the wake of a ship model with installed propeller. Presented are the results of the analysis of the wake in a longitudinal plane for different propeller revolution angles. Advantages and drawbacks of applying the PIV technique in a large facility are pointed out.

INTRODUCTION

The survey of the wake behind a ship model is a typical step in the hydrodynamic design of conventional and unconventional hulls. This type of information, which is very important for designing the propulsion system in order to obtain high-efficiency propulsion, low radiated flow noise, and fewer cavitation problems as well as lower pressure fluctuations and induced vibrations on the vessel, is obtained today by using single-point measurement techniques like the Pitot tube or Laser Doppler Velocimetry (LDV). Flow velocity measurements are also important for the validation of CFD codes; indeed, a detailed representation of turbulent aspects, especially for separated and unsteady flows, is required to enhance the accuracy of numerical predictions. The availability of reliable velocimetry techniques contributes to the goal of providing data usable as guidelines for numerical models' improvements as well as databases for their validation. The LDV techniques, which allow a very accurate and detailed analysis of the flow field (Di Felice and Lalli, 1999), have improved the analysis of ship wake flows, allowing for the highly accurate resolution of the 3D flow field in phase with the propeller. However, these measurements are expensive and require several days of facility occupancy, especially when dense measurement grids are required to resolve the flow structures (Felli et al., 2000; Esposito et al., 2000). Today, the adoption of the Particle Image Velocimetry (PIV) technique to this type of industrial application has become feasible, allowing us to obtain a detailed picture of the flow field, especially for the turbulent aspects and unsteady flows, at a reasonable cost. This is because the velocity can be simultaneously obtained in a plane even if new problems and drawbacks arise for the model and the facility setup.

Over the last few years, various PIV measuring methods have been developed depending on the different applications, the type of flow, the scale of the experiment and the size of the involved facility. The method, commonly used and adopted in the present case, records at least 2 consecutive images of small tracer particles suspended in the flow under investigation. For this purpose, particles are illuminated for a short time by a thin laser light-sheet, perpendicular to the camera axis. By measuring the particle image displacement, either by particle tracking or locally applying statistical methods (correlation technique), the 2D projection of the local velocity vector can be computed, using the image magnification factor, M, and the time delay between the 2 laser pulses.

In a large facility, one of the main requirements is to acquire a large flow-field area. This requires a recording system with a high spatial resolution as well as high sensitivity to the light intensity. Cameras or high-resolution digital video cameras (2k x 2k pixels) or digital still cameras (2k x 3k pixels) can be used to achieve large acquisition areas. However, the particle images due to the 2 shots are stored on the same frame, and this causes ambiguity in the computation of the particle displacement.

Several techniques have been proposed to overcome this problem, such as rotating mirrors (Raffel and Kompenhans, 1994; Oshwald et al., 1995), orthogonal laser polarisation pulses using calcite prism (Landreth and Adrian, 1988) or colour coding techniques (Goss et al., 1989; De Gregorio, 1997). Because each of these increases the complexity of the setup or the difficulties of the alignment, an on-line control of the measurement quality is not possible. Moreover, their reliability is questionable when tests are carried out in large facilities with high operating costs. In the present case, a progressive scanning camera has been used. Such a camera allows the recording of 2 images with a separation time down to 1 μs, thus recording the 2 laser pulses separately.

Another requirement comes from the fact that small seeding particles are needed to accurately follow the flow, which in turn requires high-powered lasers together with high-quality imaging equipment. This is particularly true in large facilities where the distance between the measuring area and the recording equipment can be considerable, in the order of 5 m or more.

This work presents the results of a feasibility study of the application of PIV to the analysis of an installed propeller wake in a large circulating water facility, with particular attention to the technical problem related to the test setup in a large facility. The analysis of the flow behind a twin-propeller model ship is per-

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