LASER DOPPLER ANEMOMETRY
IN HYDRODYNAMIC TESTING

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Abstract
Classical methods and the laser-Doppler-anemometry (LDA) application for the test section calibration of a water-cavitation tunnel is presented. The results show that the LDA is the best method for calibration and the classical methods satisfy the needs of standard tests. The advantages of the LDA are illustrated by determination of the pressure coefficient $C_p$ for a hydrofoil of a high-speed axial pump under the stationary and nonstationary conditions, as well. The velocity vector distribution is measured around the central hydrofoil of a straight grid for angles of attack $\delta = 0°$ and $25°$ and undisturbed velocity $v_\infty = 5.32$ m/s. The results of the LDA measurements are used as a basis for the definition of the boundary conditions for numerical flow simulation and $C_p$ calculation by the Fluent program. A flow visualization is made by aniline dyes and air bubbles.

Keywords: water-cavitation tunnel, pressure measurement, Pitot tube, laser Doppler anemometry, straight profile grid, numerical simulation, pressure coefficient, flow visualization.

1. Introduction

The water cavitation tunnel is a reverse-type facility with a single vertical line (see Fig. 1). The tunnel length is 7 m, whereas the transverse size is 5 m. The test section of the tunnel is closed, having a rectangular cross section with dimensions 500×450 mm and 700 mm long [1, 2]. The water cavitation tunnel is used for testing the hydrodynamic characteristics of various ships and projectiles (like torpedoes), optimum shapes of aircraft and projectiles, cavitation, and flows around various aeronautical and non-aeronautical objects and models.

Knowledge of the characteristics and flow quality in the test section is a prerequisite for using this facility for intended purposes. Calibration of the tunnel test section implies determining the flow velocity, turbulence, and boundary layer thickness related to the number of motor revolutions. The measurements of static and stagnation pressure have been made along the test-section walls using the Pitot tube. The vertical pressure distribution has been made by rake. The fluid-flow velocity was measured simultaneously along the test-section axis using the laser Doppler anemometry [3].

The pressure coefficient $C_p$ of a hydrofoil is significant in load calculations of the impeller blades, that is, the circuits of axial pumps for testing the boundary-layer characteristics, obtaining the critical pressure coefficient, and determining the cavitation number, as well as monitoring the surface cavitation appearance [4].
Fig. 1. Schematic diagrams of the water cavitation tunnel (WCT) (a and b) with a drive 1, precollector 2, collector 3, the test section 4, a small diffuser 5, the first joint 6, the concrete part of the WCT 7, blades 8, entry in the WCT 9, blades for download 10, pump 11, the LDA 12, and probe for calibration 13, scanival for pressure distribution measurement (c), and macroscopic view of the test section of the water cavitation wind tunnel (d).

Nowadays, various experimental and numerical methods [5–7] are used worldwide for determining the $C_p$. The well-known noncontact methods, for which the fabrication of small holes on the model surface is not necessary, and therefore do not cause a disturbance in the flow field, are the pressure-sensitive paints (PSP), holographic interferometry (HI), the LDA and particle-image-velocity measurements (PIV), etc. [6]. This paper presents the results on $C_p$ obtained by the flow-speed measurement using the LDA method. Combined with the experiment, a numerical flow simulation has been conducted in the Fluent program, and the coefficient $C_p$ of the hydrofoil has been determined for the experimental conditions.

2. Description of the Test Equipment

Practically, calibration is made using the following four methods [2]: a primary measuring system (PMS), the Pitot tube, the rake, and laser Doppler anemometry.