APPLICATION OF REFLECTED GRID METHOD FOR EXAMINATION OF SMALL SURFACE DEFORMATION OF MOVING FLUID

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*A version of the reflected grid method for measuring small deformations of a liquid surface during its movement is suggested. The method is used for analysis of applicability to the simplest analytical methods for calculation of liquid surface deformations above a submerged, moving cylinder with bank axis normal to **the** moving direction.*

Observations of liquid surface phenomena in laboratories are provided by means of contacted, optical, direct laser recording, still photography, and cinematography of tracers, classified in [I].

Methodical treatment of liquid surface deformation is necessary to provide deformation registration of the fluid (or the most part of it) of free surface. It is obvious that some difficulties exist for realizing such conditions by means of the contact method:

comparative difficulty and large sizes of registration equipment, as well as corruption of real phenomena by the contact detectors.

Still photography and cinematography registration are the best methods (due to the simplicity and clarity) for reconstruction of a three-dimensional picture at the base of a plane one.

In this article a version of the reflected grid method [2] is suggested [3] to measure a small surface deformation of a moving fluid [4].

Experimental investigation of a surface deformation was provided for a submerged circular moving cylinder with its axis normal to a moving direction. The scheme of the experiment is presented in Fig. 1.

The conditions of the experiments were: channel sizes, 500, 500, 3000 mm; diameter of cylinder d = 35 mm; depth of cylinder movement. *Hid* = 3.9-6.8, velocity, 0.18-0.6 m/s; Froude number (for//), Fr,, = 0.17-0.43; Reynolds number (ford = 35 mm) lO^4-$! X 10^4$.

Registration of a surface deformation during submerged cylinder movement was provided by the reflected grid method. For that a plate with plane coordinates (a grid) was placed at some angle to a liquid surface in such a manner that the reflected picture from the liquid surface was normal to an optical-axis still or movie camera.

For certain geometric parameters, for instance, angles of inclination of the grid and the camera, the distance between lines on the grid, and so on, inclination of a studied surface at points may be calculated using simple geometric relations.

An example of a grid reflected from undisturbed water surface (the reflected picture is adequate to the grid) is shown in Fig. 2. For a disturbed surface (for instance, a wave), the lines of the reflected grid are curved (Fig. 3), so that the pressure lines correspond to rises of liquid surface.

A photographic image (in negative form) of a disturbed surface was treated on the

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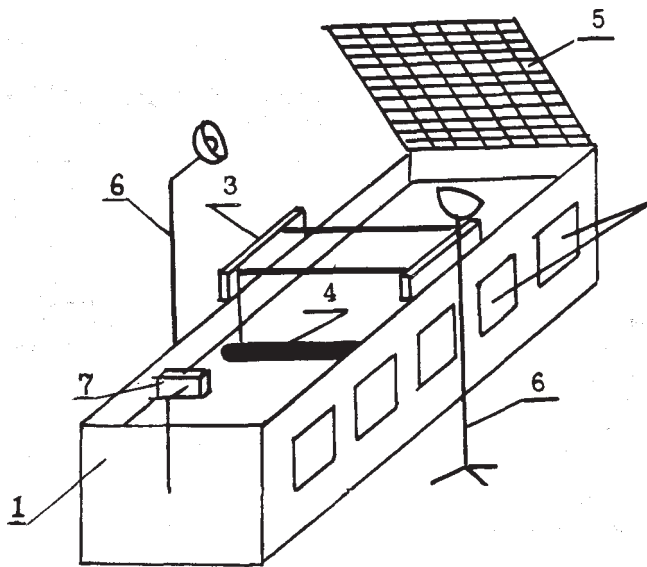
Fig. 1 The scheme of the experiment for investigation of surface waves above submerged moving cylinder: 1, channel; 2, windows; 3, moving cart; 4, cylinder; 5, grid; 6, lamps; 7, still or movie camera.
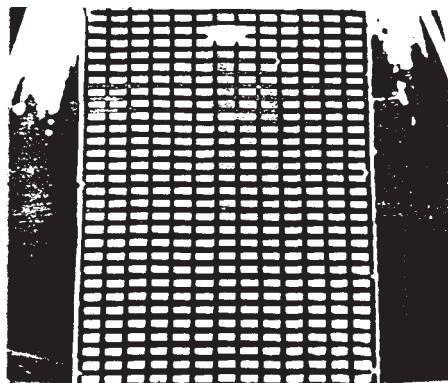
Fig. 2 Photo of a grid, reflected from undisturbed water surface.

basis of a scheme as in Fig. 4. The examined negative was placed on the table of a stereocomparator that in this case worked like a monocomparator. The stereocomparator allows one to measure points of coordinates on the negative with a mean error of 0.002 mm. The data from the stereocomparator were input to an Era-1300.01 computer to get the inclination angles and surface rise calculations. The results were printed and output to a monitor and a plotter. The obtained profile of surface made it possible to estimate the degree to which a free surface was distinguished from an ideal smooth one.

In the present experiments the reflected grid method resulted in the opportunity to
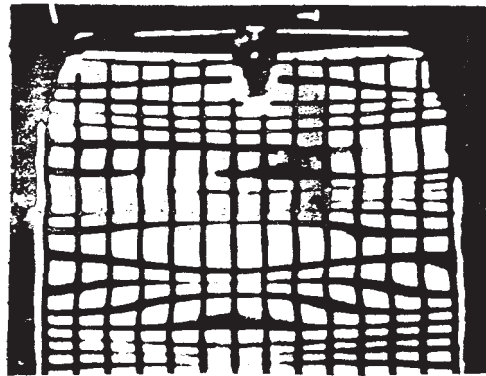
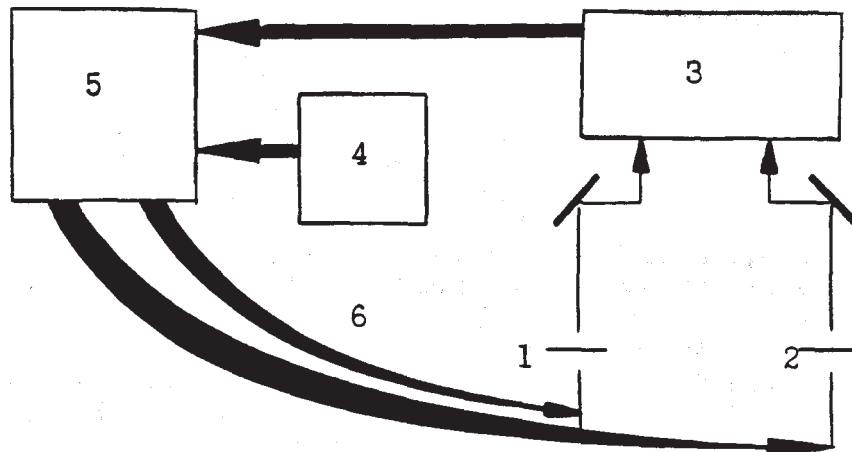**Fig. 3** Distortion grid lines from disturbed surface.

Fig. 4 General scheme of the experimental treatment: 1 or 2, investigated negative; 3, stereo-comparator; 4, block for displacement registration; 5, computer; 6, table displacement; 7, registration starting.

obtain sensitivity for inclination angles of a surface to nearly 0.001 with precision 0.00025.

The typical profile of a surface wave which was constructed for the moving submerged cylinder by the reflected grid method is shown in Fig. 5. Here 8 = a rise of liquid surface; d = cylinder diameter; Fr = $VI \sqrt{gH}$ = Froude number; U = velocity; x = distance passed by cylinder; and g = gravity constant. The calculation dependence is also plotted in this figure also [5]. It was found that the method of calculation gave a systematic difference with experimental data that may be explained by an imperfection of the linear theory. Some generalization of experimental and calculation data and their comparison are plotted in Fig. 6 (dependence of nondimensional amplitude of surface wave on Froude number A(l/Fr^).

It is seen that calculation data for the linear theory are two to three times lower than experimental data. Satisfactory agreement was obtained between experimental and calculated data, taking into account a drag force according to "shallow water" theory.
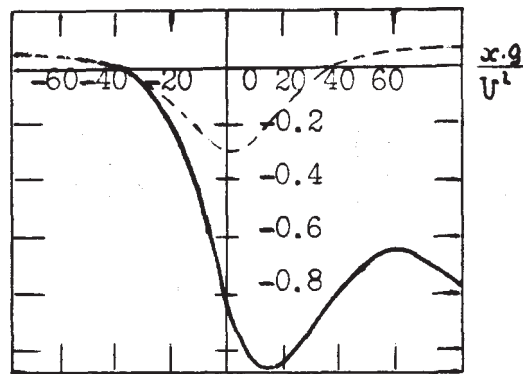
Fig. 5 Relation of surface water profile and parameter x-g/U^{2}'.—
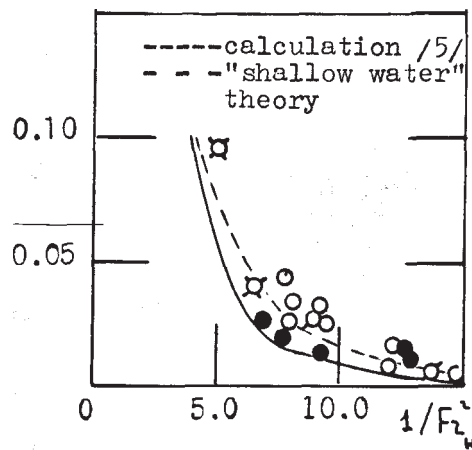————, experiment; ——————, calculation [5].

Fig. 6 Relation of nondimensional parameter for surface
wave amplitude and reciprocal Froude number.

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