

# A Method to Measure the Drag Force of the Immersed Body

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In order to make an accurate measurement of the drag force of the immersed body against the stream, a simple device was devised by attaching the strain gauge on a steel plate.

It has become clear that direct measurement of the drag force of the immersed body by use of the device is feasible, and also the value obtained by indirect measurement which has been employed in this laboratory must be revised by approximately 10%.

## Introduction

One of the method to design a new fishing gear or to improve an old one is model experiment using water tank. The water tank experiment of the fishing gear has been carried out for the respective purpose in two ways. One is the most popular method which was first presented by Tauti using a model made according to the law of similarity between model and full-scale net. The other is to verify the theoretical analysis of the gear. This method is mainly employed in this laboratory.

The data obtained in the course of experiment are quite necessary for research. For example, in the study of tow net, the distance between danlenos, the height of net mouth and total resistance of the net are three important factors that must be obtained. The distance between danlenos or the height of the net mouth is obtained without difficulty by direct measurement or by measuring with a rule the photograph taken in the course of experiment. However, the accurate measurement of total resistance of the net in water is not obtained easily.

Recently, the commercial strain gauge is employed popularly in the field of research work. It is, however, impossible to use it directly in water to measure the force acting on the net. In this laboratory, therefore, the force acting on the net in water is measured by use of an unbonded transducer equipped over the position of the net in air and connected by a string to the immersed net through a pulley in order to change the direction of the string at right angles. Therefore, as the force obtained by the transducer is loaded with both the total force of the immersed net and the frictional force of the pulley, it is considered that the value obtained in the course of experiment requires some correction.

Here, in this report, a simple device to measure the drag force of the immersed body is described and the revised value against the conventional experiments is sought.

## Method

In order to obtain the influence of the immersed pulley, the resistance of an

immersed body which is towed against the stream in the water tank was measured directly as well as indirectly through the pulley as shown in Fig. 1. The immersed

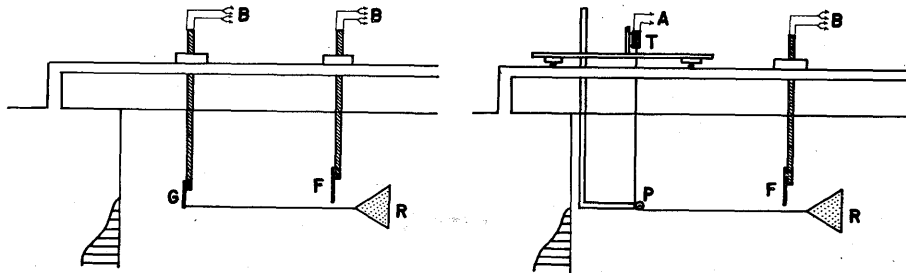


Fig. 1. Schematic view of Experiment I (left) and Experiment II (right).

Key- A, dynamic strain amplifier; B, bridge box;  
F, flow speed measuring device;  
G, steel plate bonded with strain gauge;  
P, pulley; R, immersed body;  
T, unbonded transducer.

circular cone shape body made of polyethylene was loaded with lead so as to be stable in the stream.

Hereinafter, the direct measurement refers to Experiment I and the indirect measurement to Experiment II.

### Experiment I

The immersed body, R in Fig. 1, was connected directly to the steel plate (G) ( $218 \times 12 \times 0.8$  mm) by a string. The hydrodynamic force acting on the immersed body deforms the steel plate by flow. Therefore, the strain gauge (Kyowa KP-10-A1-17) was bonded upon the steel plate on both sides according to the active dummy method as shown in Fig. 2. The bonded gauge was covered with a coating material to be

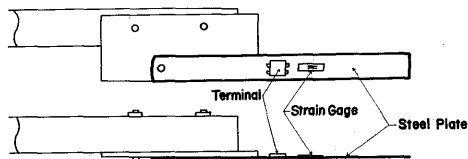


Fig. 2. Schematic view of force measuring device.

made water-tight. The terminal of the strain gauge was connected to the bridge box (Kyowa DB-120K), B in Fig. 1, the dynamic strain amplifier (Kyowa DPM-1N) and the linear coder (Model WTR 281).

### Experiment II

The immersed body was connected by a string to the unbonded transducer (Kyowa 120T-200C) shown by T in Fig. 1. The pulley (P) was employed to change the direction of the string at right angles. And the transducer was connected to the dynamic strain amplifier (A) and then to the linear coder.

### Measurement of the flow speed

In the course of experiment, the exact value of flow speed must be obtained, because the force of the immersed body varies with a variety of flow speed. The electric current meter (Dentan CM-1B) was employed to measure the flow speed in previous papers<sup>1, 2, 3, 4, 5</sup>, however, this was not so sensitive to follow the full variety of flow speed, especially in low flow speed where the propeller of the current meter could not swing due to the friction of its axis. Therefore, the strain obtained by the deformation of the steel plate by flow was converted into the flow speed.

The steel plate which was bonded with the strain gauge on both sides was depressed and carved in part so as to deform easily even at slow flow speed as shown schematically in Fig. 3.

The strain by flow was recorded simultaneously with the force measurement by the linear coder.

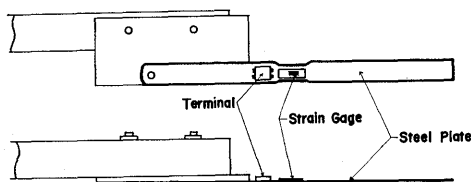


Fig. 3. Schematic view of flow speed measuring device.

### Result and Discussion

As the recorded values on the chart of the linear coder was shown in strain, it was first converted into the value of weight in gram. The relation between the strain and weight in gram for the force measuring device is shown in Fig. 4 and for the flow speed measuring device in Fig. 5.

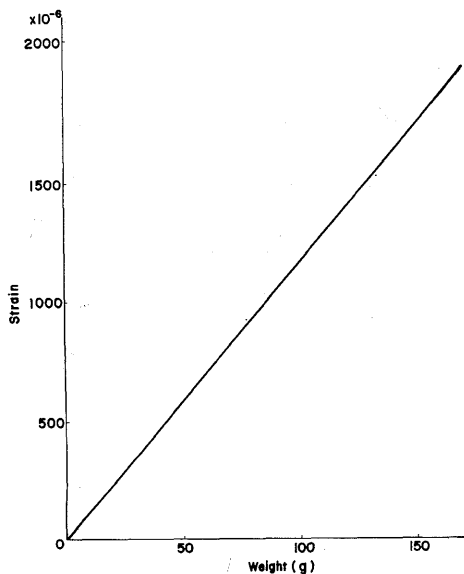


Fig. 4. The relation between the strain and weight for the force measuring device.

The flow speed in cm/sec was calculated by the equation

$$R = \frac{1}{2} C_d \rho V^2 A,$$

where  $R$  is the drag force of the immersed plate,  $C_d$  the drag coefficient,  $\rho$  the density of fluid,  $V$  the flow speed and  $A$  the area of steel plate in the stream. And the relation between the strain and flow speed and also towing force is shown in Fig. 6. In the figure,

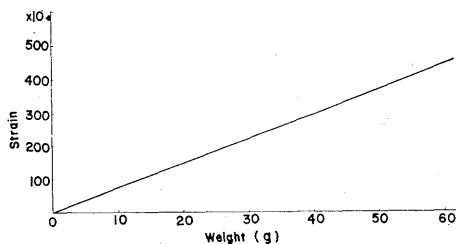


Fig. 5. The relation between the strain and weight for the flow speed measuring device.

the curved line S shows the relation between the strain and flow speed, and the point marked with a circle is the drag force of the immersed body which is obtained by subtracting the drag force of the steel plate that is calculated by the above mentioned equation from the recorded value in Experiment I. Because, the value obtained in Experiment I contain both the drag force against the stream of the steel plate and that of the immersed body. The point marked with a double circle is the value obtained in the course of Experiment II. The straight lines I and II were drawn by the method of least squares.

By the use of Fig. 6, the drag force of the immersed body which is towed against the stream of any water speed is obtained immediately. For example, as shown by a dotted line in Fig. 6, consider that  $V_a$  is an arbitrarily chosen water speed and then

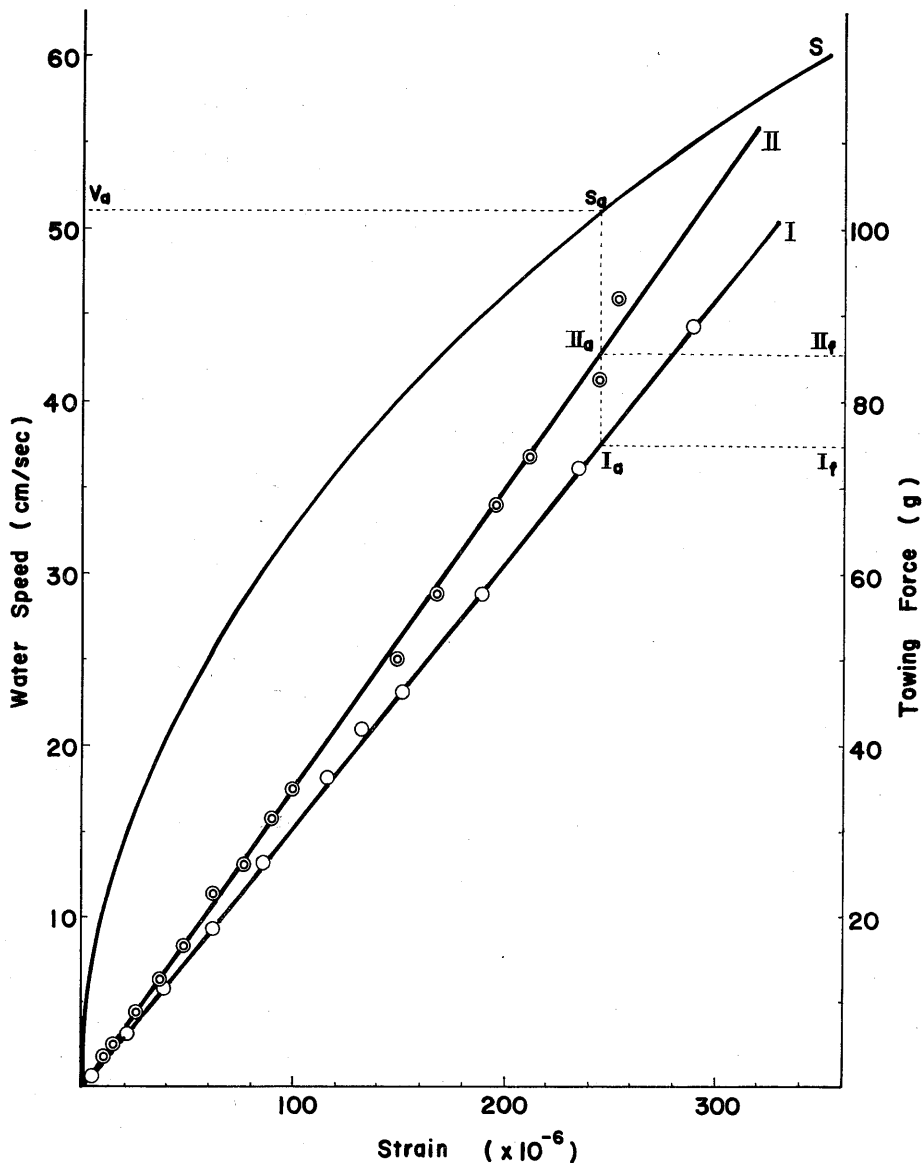


Fig. 6. The relation between the strain and the towing force and also flow speed.

the dotted line which is drawn horizontally from the point  $V_a$  intersects the curved line  $S$  at the point  $S_a$ . Then, the line which is drawn from  $S_a$  at right angles downward crosses the lines  $I$  and  $II$  at the points  $I_a$  and  $II_a$ , and the force value of these points is seen at  $I_f$  and  $II_f$ , respectively. It is considered that the difference between the values of  $I_f$  and  $II_f$  is caused by the frictional force of the immersed pulley.

The difference rate against the values of Experiment II is shown in Fig. 7. As seen in the figure, the rate is large at low flow speed and becomes smaller following the increase of water speed. And it becomes nearly constant in the range of flow speed exceeding 20cm/sec. In this range the rate appears to be 10-12% as shown by the dotted lines in the figure. Therefore, the accurate drag force acting on the

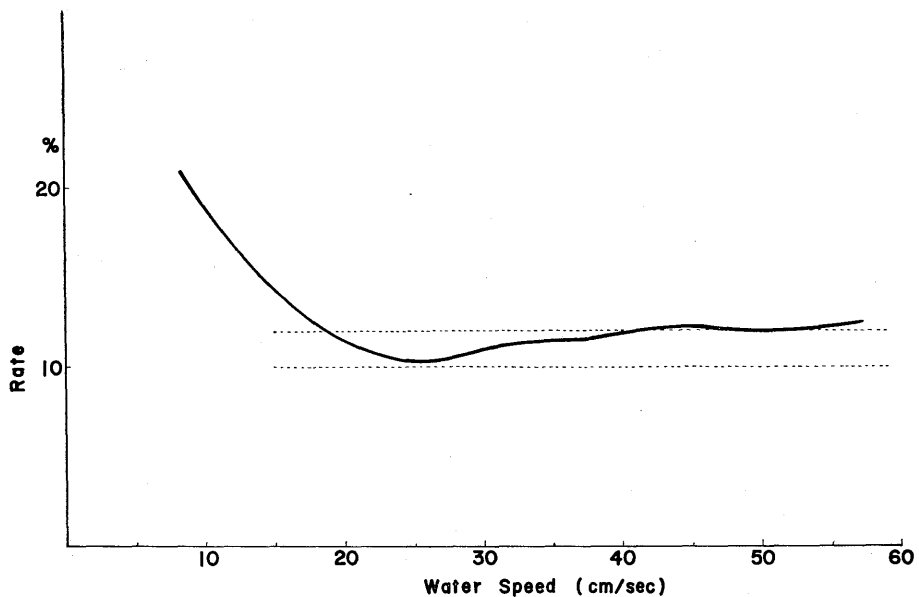


Fig. 7. The difference rate against the values of Experiment II.

immersed body must be the value deducted approximately by 10% from the value obtained by the method of Experiment II.

After all, the best method to measure the drag force of the immersed body against the stream is a direct measurement, but the circumstance of water prevents us from doing so. However, in this experiment it has become feasible to a certain extent to use the strain gauge in water only if it is made perfectly water proof.

And also it has become clear that the drag force of the immersed body obtained by the conventional method using a pulley must be corrected by deducting approximately 10%.

### References

- 1) NAKASAI, K. and E. FLORES : Theoretical studies on the mechanical characteristics of two-seam trawl net. *This Bull.*, **32**, 113-128 (1971)
- 2) FLORES, E. and K. NAKASAI : On the comparison between two-seam trawl net and four-seam trawl net. *ibid.*, **32**, 129-134 (1971)
- 3) AHMAD, M. and K. NAKASAI : The mechanical characteristics of a six-seam trawl net. *ibid.*, **36**, 75-91 (1973)
- 4) AHMAD, M., H. NISHINOKUBI and K. NAKASAI : The mechanical comparison of a six-seam and a four-seam trawl. *ibid.*, **36**, 93-101 (1973)
- 5) KAKUI, A., H. NISHINOKUBI and K. NAKASAI : The mechanical study on the west Japan small type tow net. *ibid.*, **36**, 103-116 (1973)