MODEL EXPERIMENT ON THE TIDAL AND OCEAN CURRENTS THROUGH THE STRAIT OF TSUGARU

Seiti YAMAGUTI

Faculty of Fisheries, Hokkaido University

Introduction

The current through the Strait of Tsugaru may be affected by the tidal phases on both the Japan Sea side and Pacific Ocean side, and also by the steady current called "Tsusima Danryu", which enters into the Strait. The calculation about the current, which results from the above two effects, is by no means easy, so the writer decided to make the model experiment to solve the problem.

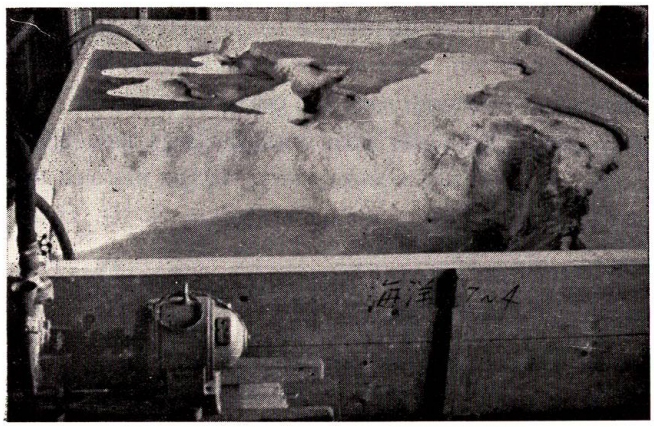

Fig. 1. Experimental tank
300×360×60 in centimetres

The size of the experimental tank is 300 × 360 × 60 in centimetres, as shown in Fig. 1, and the diminished ratios of the figure of the Strait are 5.0×10^{-4} and 1.25×10^{-5} in vertical and horizontal scale respectively.

It was assumed that the tidal and ocean current may be represented by the equations

$$\frac{\partial}{\partial t}(u,v) = -g\left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}\right)\zeta$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$(w)_{z=0} = -\frac{\partial \zeta}{\partial t} \quad ; \text{ at the surface,}$$

$$\left(u\frac{\partial z}{\partial x} + v\frac{\partial z}{\partial y} - w\right)_{z=Z} = 0 \quad ; \text{ at the bottom,}$$

neglecting the viscosity, the friction, the density anomaly et cetera.

If the coefficients of scale for (u, v), w, (x, y), z, ζ, t, are denoted by V, W, L, H, Z, T respectively, then the conditions for dynamical similarity may be as follows:

$V/T=Z/L$, $W/V=H/L$, $W=Z/T$ or $Z=H$, $T=L/\sqrt{H}$, $V=\sqrt{H}$, and $W=\sqrt{H^3}/L$. Here, $L=1.25 \times 10^{-5}$, $H=5.0 \times 10^{-4}$ then, $Z=5.0 \times 10^{-4}$, $T=5.58 \times 10^{-4}$, $V=2.24 \times 10^{-2}$. Thus, the current velocity, 1 knot may correspond to 1.15 cm/sec.

A comparable experiment in the case of Sagami Bay was already made by Prof.

Mitsuyo Okada and his assistant, Mr. Kiyoakira Miyoshi, and reported in the preliminary reports of the Training School of Fisheries in Tokyo, Vol. 29, 1933–1934.

Apparatus for Experiment

The tank, the size of which is already noted, was made of wooden boards with the thickness of about 4 cm, and the inner wall was covered with iron plate to make it water-tight. The size of the Strait in the tank was determined so as to include Mutsu Bay and Funka Bay and also a large area of the Pacific Ocean to make the boundary effect on the Pacific Ocean side small. That is, the total area of the tank was made to represent the large area between 139°40′–143° East Longitude and 40°50′–42°50′ North Latitude.

Surface configuration was transcripted from the chart in the ratio 1/80000, and the depth in each part in the Strait was measured from the surface by hanging a string of length in the ratio 1/2000 to the actual length. The whole configurations of land, islands, and the bed of the Strait were concreted with sand and cement.

Using a water pump of 1/2 horse power, the water from Pacific Ocean side being pumped up, and poured into the Japan Sea side, the necessary level change between the two sides, about 1 millimetre was secured in order to obtain a current in the model Strait.

Method of Experiment

Using a bulb, the pumping water mass was controlled to make various current velocities. In this case, rather fast current, slow current and the inverse current were obtained, the last of which appeared at the instant of stopping the pump.

Various directions were given to the currents which enter into the Strait from the mouth of Japan Sea side, applying the law of reflection by pouring water from the pump into the tank on Japan Sea side, by a wall of wooden boards rotated about the vertical axis.

To photograph the figures of stream lines in the Strait, abundant bits of tin foil, were scattered, the size of each of which was about 1 centimetre on each side, on the area near the mouth of the Strait on Japan Sea side. Lighting the whole area of the tank by many electric lamps, photographs were taken of the moving states of the tin foil bits from the ceiling about 4 metres height.

Seeing the arranged figures of tin foils during a short period of 2 seconds or 6 seconds, one may be able to determine the features of stream lines in the current through the Strait. Thus representative 6 photographs were obtained as follows:

(a) Exposure = 6 sec, rather fast inverse current

(b) Exposure = 6 sec, rather fast current

(c) Exposure = 6 sec, slow current

(d) Exposure = 2 sec, rather fast current
(e) Exposure = 6 sec, rather fast current
(f) Exposure = 2 sec, rather fast inverse current.

These photographs are shown in Fig. 2.

Fig. 2, (a). Exposure=6 sec, rather fast inverse current.

Fig. 2, (d). Exposure=2 sec, rather fast current.

Fig. 2, (b). Exposure=6 sec, rather fast current.

Fig. 2, (e). Exposure=6 sec, rather fast current.

Fig. 2, (c). Exposure=6 sec, slow current.

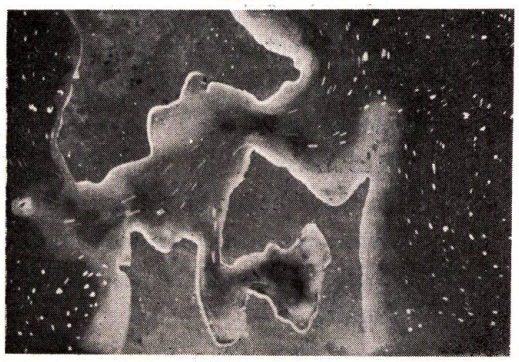

Fig. 2, (f). Exposure=2 sec, rather fast inverse current.

Results and Discussion

Investigations on the current through the Strait of Tsugaru, using drift bottles, have already been made a great many times by the Authorities of the Marine Observatory in Hakodate and of the Head Quarters of the First Division of Maritime Safety Board. The results are reported as follows:

(a) Bottles are picked up at various points along the coast of the Strait.

(b) Among many bottles, some of them took the time of 200 hours to run through the Strait from the Japan Sea side to Pacific Ocean side.

(c) There were some bottles which drifted to the direction of Funka Bay.

(d) Those bottles, which drifted on the main current directly towards the Pacific Ocean side within a necessary and sufficient time, about 30 hours, were rare.

(e) Most of the bottles, which flowed out of the Strait to the Pacific Ocean side, drifted towards the south along the Pacific coast.

(f) Existence of some circulations of the currents was suspected, but the areas and their positions were not so clear.

By the model experiment, executed at this time, the following important matters could be ascertained:

(a) There exist clock-wise circulations in the regions both to the west and east of the Ôma promontory, on the side of Aomori Province, and also a counter clock-wise one on the side of Hokkaido, all on a large scale or in wide areas.

(b) Tin foil bits, which rode on the main current through the middle part of the Strait and flowed directly towards the Pacific Ocean side were only 20 or 30 per cent of the total tin foil thrown into the mouth of the Strait on the Japan Sea side.

(c) The reason why a drift bottle took 200 hours to pass through the Strait may become clear. Some bottles may become involved in the circular motion of the current and may remain in the Strait for so long a time as about 200 hours.

(d) Some tin foil pieces were seen which flowed to the direction of Funka Bay.

(e) The modes of the circulation of the currents do not change with variations in the direction of the current entering into the mouth of the Strait on the Japan Sea side. The modes of circulation currents may be settled by the configurations of the sea-bed, the bays and the land wall on both sides of the Strait.

It is hoped, from these boundary conditions, that such circulation currents on a large scale, as mentioned above, may be deduced by some theoretical oceanographer in the near future, and also that these resultant determinations may be utilized in the

fields of fisheries and navigation.

After all, in this model experiment, it may be said that the law of similarity might have held in some measure, but the *Coriolis* force and the Oyasiwo current, as a matter of course, could not be realized.

In conclusion, the writer wishes to express hearty thanks to Mr. K. Kato, in his laboratory, who has rendered valuable assistance through the course of the experiment.