Annual Meeting of Korean Society of Coastal and Ocean Engineers
Sung Kyun Kwan University, 6-7 October 1995

**Hydraulics of a two-layer rotating flow; Application to the Korea Strait**

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**1. Model**

The Korea Strait becomes deeper than 200 m from south to north in general except coastal area, whereas its southern part is shallower than 125 m except for a deep trough (Fig.1). The flow in the Korea Strait could be simplified as two layers (Isobe, 1995); the Tsushima Warm Water in the upper layer and the Korea Strait Bottom Cold Water (KSBCW) in the lower layer (Fig.2). A hydraulic model with two active layers in a rectangular strait is investigated to understand the flow dynamics under the varying channel depth, following Hogg (1985). Consider the situation sketched in Fig. 3 in which homogeneous two layers of fluid move along a channel of depth H(y). This section might represent the D-line of Fig.1 whose depth is about 150 m. We assumed that the flow is inviscid in a steady state and the along-channel velocity component v is much greater than the cross-channel component u. The potential depths of the upper layer and the lower layer are $\hat{D}_1$ and $\hat{D}_2$ respectively, and the channel width is fixed. Potential depths, density ratios and transport parameters are as $\hat{D}_1 = 1.2$, $\hat{D}_2 = 1.5$, $\hat{g} = 604.176$, $Q_1 = 1.06$, $Q_2 = -0.053$, $\hat{\psi}_1 = -0.5Q_1$, $\hat{\psi}_2 = 0.5Q_2$.

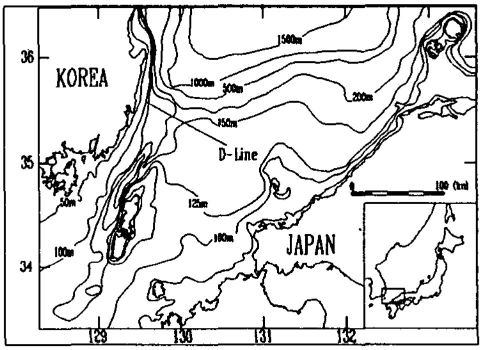

Fig. 1 Bathymetry of the Korea Strait

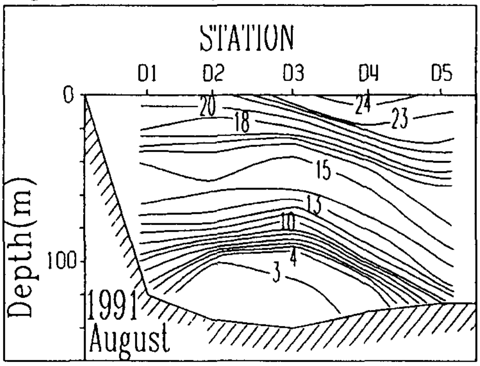

Fig. 2 Temperature section of D-Line (see Fig.1) in August 1991.

## 2. Results

In Fig.4 the layer width configurations for a specified upstream state are shown as a function of the channel depth. All the transport for the upper moving layer is along the right (eastern) boundary in the upstream basin and that for the lower layer is along the left (western) boundary. When the depth is shallower than a separation point (about $H_s = 230m$), the lower layer leaves the eastern boundary. The lower layer becomes narrower after that point, as the depth decrease. For depths more shallow than 131 m no solution is found which are continuous with those at slightly shallower depths. As the channel deepens again, the solution switches in a smooth way to another branch.

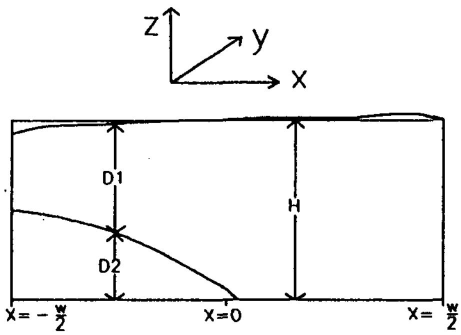


Fig.3. Model section with two moving layers.

The Korea Strait, the width of the lower layer (6 km) after control is much smaller than those observed (30~50 km) in the section-D, whereas that before control (40 km) it is comparable. Presumably the flow in the section-D is before control.

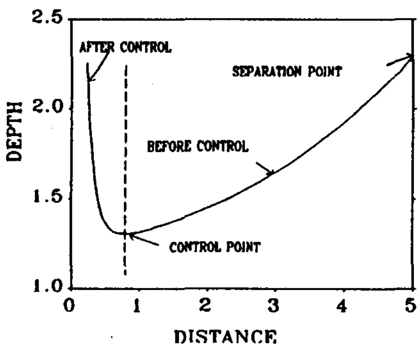


Fig. 4. The width of the lower layer.

The lower layer shrinks along the left boundary and becomes thinner as the channel shallows, which causes negative relative vorticity to increase. Fig.5 shows the configuration of the lower layer and current structure of each layer. The increase of the relative vorticity increases the speed of the counterflow along the western boundary and makes the interface dip down at the western boundary also.

Increase of the water depth and separation of the lower layer from the eastern boundary makes the upper layer stretch in eastern part, which causes the positive vorticity and the velocity along the eastern boundary to increase to conserve the potential vorticity. However, the thickness of the upper layer near the western boundary decreases due to the presence of the lower layer, which makes the negative vorticity and the velocity along the western boundary increases.

If the lower layer in the northern upstream locates deeper by 20 m, that is, if the Bernoulli potential of the lower layer in the upstream decrease, the lower layer becomes thinner and narrower in the strait. Thin lower layer in the strait causes negative relative vorticity of the upper layer to decrease and northward speed of the upper layer along the western boundary to decrease. Low speed makes the interface near the western boundary dip down (Fig.6).

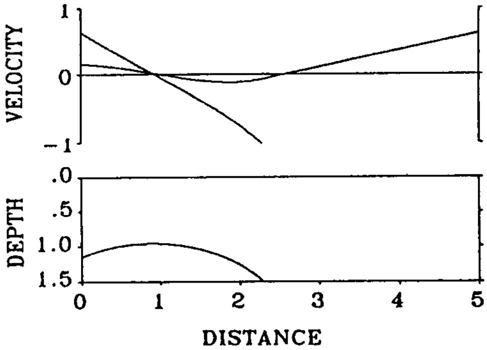


Fig.5. Layer configuration and down channel velocity for large Bernoulli potential of the lower layer.

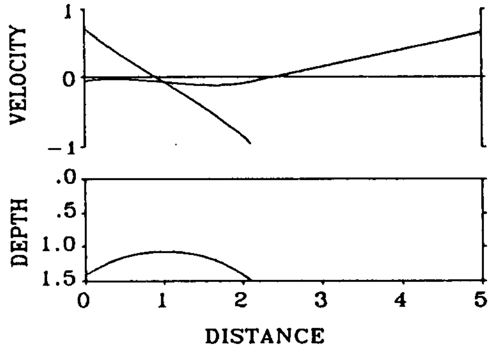


Fig.6. Same as in Fig.5 except for small Bernoulli potential.

## 3. Application

The lower layer flowing south in a shallow meridional channel separates from the eastern boundary due to a rising bottom in order to conserve the potential vorticity. After separation, the lower layer hugs the western boundary rapidly as the channel shallows further. This may explain why the KSBCW appears only along the Korean coast.

The northward flow in the upper layer gains a positive relative vorticity to conserve potential vorticity, because the bottom topography becomes deeper from south to north. Therefore, the northward velocity has its maximum on the eastern boundary, corresponding to the branch of the Tsushima Current along Honshu. But, the upper layer near the western boundary experiences shrinking of its water column because of the presence of the lower layer, generating a negative relative vorticity. This negative relative vorticity intensifies the northward flow of the upper layer near the western boundary. This is believed to be the formation mechanism of the so-called East Korean Warm Current.

If the lower layer in the northern basin locates deep and has a small

Bernoulli potential such as in winter (Cho,1995), the thickness of the lower layer in the strait becomes thinner. In that case, the cold water could not make the upper layer along the western boundary generate enough negative relative vorticity and, therefore, the branch along the Korean coast is absent in winter as Isoda and Saitoh (1994) reported. The positive relative vorticity on the eastern side and the negative relative vorticity on the western side together induce a southward flow in the central region of the strait. Measured currents (Miita and Ogawa, 1982) support this flow.

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