論 文

A STUDY ON THE METHOD OF TURBULENCE STIMULATION IN THE SHIP MODEL TOWING TEST

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模型船 曳引試驗에 있어서의 亂流促進 方法에 關한 硏究

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槪 要

Model 試驗에 있어서 지금까지 使用해온 여러가지 Stimulator 中에서 Sand strip 와 Pin 의 亂流促進効果를 比較 檢討하고 서울 大學校 工科大學 模型船 曳引水槽에서 使用可能한 Model size 를 考慮하여 가장 適切한 Stimulation method 를 調査하였다. Sand strip 와 Pin 의 取付要領은 Fig. 2와 같으며 그 結果는 Fig. 3, Fig. 4 및 Fig. 5에 주어져 있다.

얻어진 結果는 다음과 같다.

1) $V/\sqrt{L}=0.75$ 以下에서는 Sand strip method (1)이 가장 効果的인 Stimulation 方法이며 Rn 가 적은 範圍에서는 方法 (1)과 같이 activator 로써 두 개의 Sand Strip 를 要한다.
2) $V/\sqrt{L}=0.75$ 以上, 0.92 以下에서는 Sand strip 의 方法 (2)가 effective stimulation method 이다.
3) Pin stimulator 의 境遇, $V/\sqrt{L}=0.92$ 以上에서는 method (6)이 効果的인 Stimulation 方法이다.
4) Bare hull 의 境遇, $Rn=7.4\times10^5(V/\sqrt{L}=0.55)$ 以下에서는 Ct 가 Schoenherr formula 에 依한 C_f 보다도 적었다는 것은 特히 注目할만한 事實이며 그 理由는 Rn 가 너무 적기 때문이다. 故로 低速 Range 에서의 effective Stimulator 使用이 要緊한 問題이다.

1. INTRODUCTION

In order to obtain a perfect turbulence in model tests, various turbulence stimulators have been used, for example, sand strips have been used at the Netherland ship model basin, Hamburgische Schiffbau Versuchsanstalt, Institute De Presquisas Technologicas in Sao Paulo, and at many testing laboratories of America, and pins have received considerable use in connection with development of a series of trawler hull forms of prismatic coefficients 0.55, 0.60, 0.65, and 0.70 at the Webb Institute of Technology by prof. Cedric Ridgely-Nevitt [1]**.

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** Number in parenthesis indicates the number of references listed at the end of the papers.

As the S.N.U. ship model towing tank having gravity type dynamometer is a small tank, it imports us to know a certain successful turbulence stimulation method because of the adaptable size of the models.

The author made a series of the problems of turbulence stimulation using sand strips and pins to find the most optimum stimulation method for 4 feet model.

2. RELATED THEORY

The sum of the forces exerted by the water, represented by the so-called total resistance of hull, can be decomposed according to William Froude, as skin friction resistance and wave making resistance, and depend on the dimension, form, speed, and surface roughness of the model, temperature, density, viscosity and initial turbulence of water, and acceleration of gravity.

The total resistance is usually computed by the following formula:

$$R_t = C_t(\rho/2)S\ V^2 \tag{1}$$

where

R_t : total resistance in pounds

C_t : total resistance coefficient, dimensionless

ρ : mass density, lb-sec^2/ft^4

V : speed, ft/sec

S : wetted surface area, ft^2

In general, the coefficient of total resistance may be formulated as

$$C_t = f(\text{form},\ R_n,\ \frac{U}{U_0},\ \frac{I}{K},\ F_n,\ W) \tag{2}$$

where

R_n : Reynold number, dimensionless

$\frac{U}{U_0}$: initial turbulence of water

$\frac{I}{K}$: roughness of the surface

F_n : Froude number, dimensionless

W : Weber number

Furthermore, the C_t, following the Froude assumption, can be decomposed as the C_f and C_r, and expressed by

$$C_t = C_f(R_n,\ R_{nt},\ \text{Form},\ \frac{I}{K}) + C_r(\text{Form},\ F_n,\ R_n) \tag{3}$$

where

R_{nt} : Reynold number at the point of transition of the flow

C_f : coefficient of frictional resistance

C_r : coefficient of residual resistance

Formula (3) shows that Cf and Cr can be seperated from C_t, assuming the effect of the R_n on C_r is neglegible, we may write,

$C_r(\text{from},\ F_n,\ R_n) \doteqdot C_r(\text{Form},\ Fn)$

On model test, R_t is measured, so that C_t may be calculated from the equation (1), on the other hand, the coefficient of frictional resistance is estimated from the Schoenherr's formula,

$$\frac{0.242}{\sqrt{C_f}} = \log_{10}(R_n \times C_f) \tag{4}$$

then, the coefficient of residual resistance may be obtained by subtracting C_f from C_t, that is,

$$C_r = C_t - C_f \tag{5}$$

and

$$(C_r)_{model} = (C_r)_{ship} \tag{6}$$

3. TESTING METHODS AND RESULTS

The model used for this experiment was SV(T)-1, form characteristiecs of which are shown in Table 1 and Fig. 1. The SV(T)-1, designed and constructed by Prof. Keuck Chun Kim, is of straight framed V-bottom and of an equivalent hull form to the W-8 out of the trawler hull form series developed by Prof. Cedric Ridgely-Nevitt [1], [2].

For turbulence stimulation, twelve methods were employed; five with sand strips and seven with pins, for the former natural silical sands of 0.8mm ϕ and 0.2-1.16mm ϕ were used and for the latter pins of $\frac{1}{4}'' \times 1/16''$, $3/16'' \times 1/16''$ and $1/8'' \times 1/32''$.

Detailed schedules of the experiments carried out was as the followings (refer to Fig. 2).

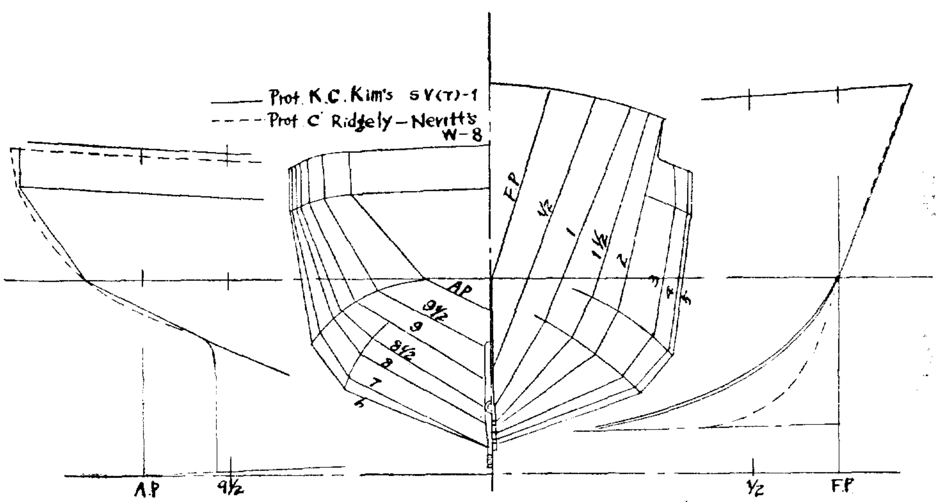

Fig. 1 Body plan and profils of bow and stern of SV(T)-1

Table 1. SV(T)-1 model characteristics:

Length, BP(ft)	4.00	Wetted surface area(ft^2)	4.42
Length, LWL(ft)	4.12	Block coefficient	0.497(0.482)
Beam, molded(ft)	0.88	Prismatic coefficient	0.650(0.63)
Draft, amidship(ft)	0.38	Water plane coefficient	0.780(0.757)
Displacement, S.W(lb)	43.01		

Note: Form coefficients in parentheses are those based on LWL.

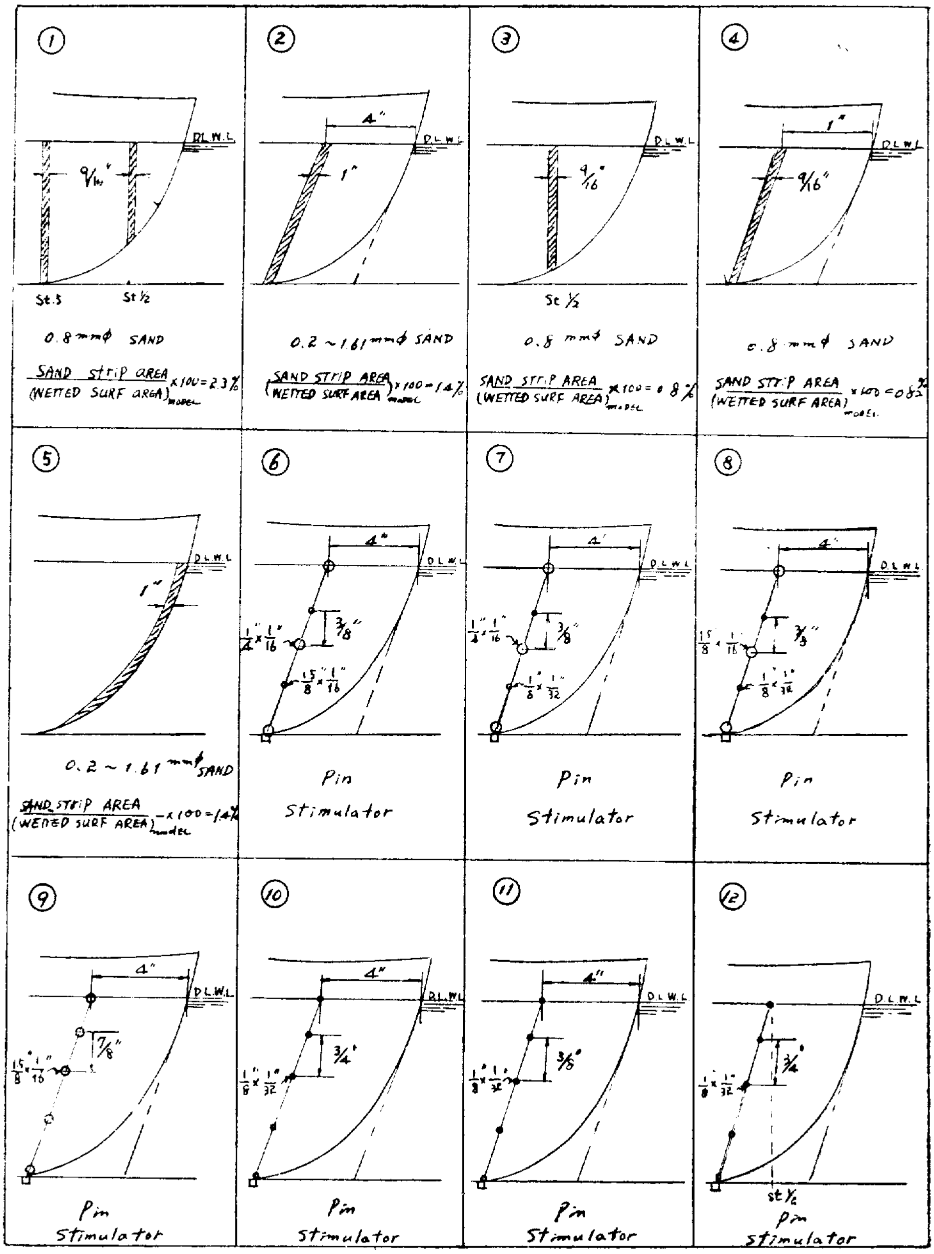

Fig. 2 Fitting methods of sand strip and pin stimulator

SAND STRIP.

Method 1. Two sand strips of 9/16″ width with 0.8 mm ϕ sand, one of which was located on the station 1/2 and the other on station 5 as an activator of the turbulence flow. Sand strip area ratio regarding wetted surface area of the model 2.3%.

Method 2. One sand strip of 1″ width 0.2 - 1.61mm ϕ sand, located along a line 4″ aft of the stem.
Sand strip area ratio 1.4%.

Method 3. One sand strip of 9/16″ width with 0.8 mm ϕ sand, located on the station 1/2.
Sand strip area ratio 0.8%.

Method 4. One sand strip of 9/16″ width with 0.8 mm ϕ sand, located along a line 1″ aft of the stem,
Sand strip area ratio 0.82%.

Method 5. One sand strip of 1″ width with 0.2 - 1.61 mm ϕ sand, fitted along the bow in both sides as shown in Fig. 2.
Sand strip area ratio 1.4%.

PINS :

As it is shown in Fig. 2, a single row of alternate large and small pins was fitted along the specified line on both sides of the model.

Method 6. 1/4″dia × 1/16″ thick and 3/16″dia × 1/16″ thick; spaced 3/8″ apart along a line 4″ aft of the stem.

Method 7. 1/4″dia × 1/16″ thick and 1/8″dia × 1/32″ thick, spaceed 3/8″ apart along a line 4″ aft of the stem.

Method 8. 3/16″dia × 1/16″ thick, spaced 3/8″ apart along a line 4″ aft of the stem.

Method 9. 3/16″dia × 1/16″ thick, spaced 7/8″ apart along a line 4″ alt of the stem.

Method 10. 1/8″dia × 1/32″ thick, spaced 3/4″ apart along a line 4″ aft of the stem.

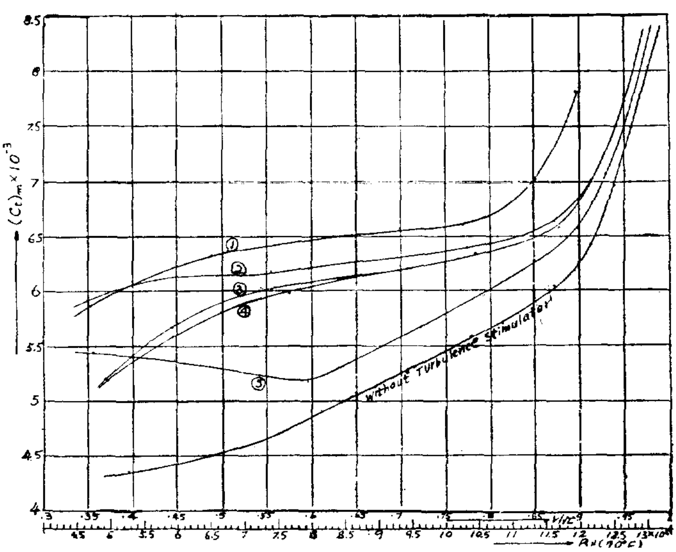

Fig. 3 C_t vs. $V/\sqrt{L}$

(For sand strip)

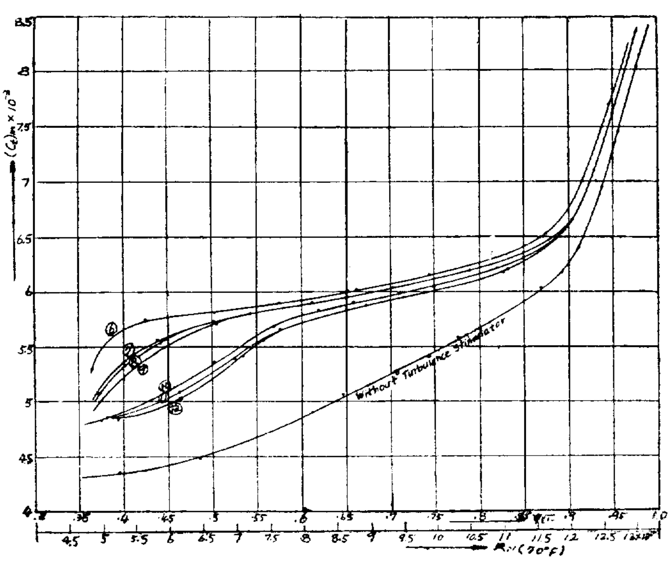

Fig. 4 Ct vs $V/\sqrt{L}$

(For pin stimulator)

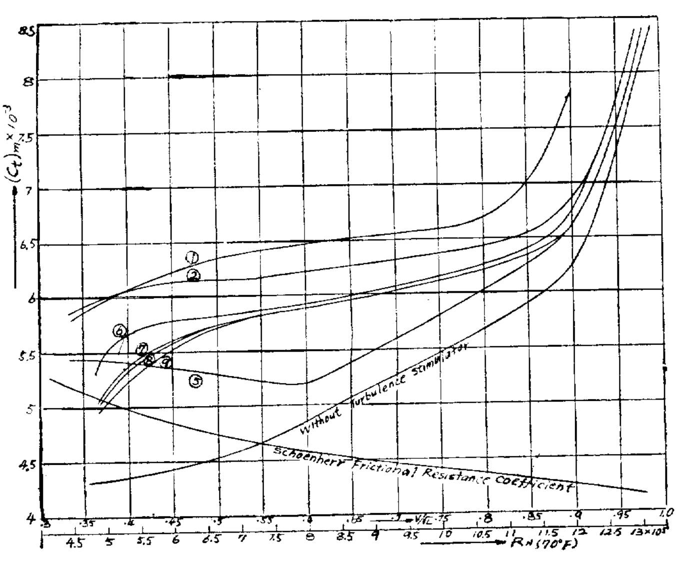

Fig. 5 Ct vs $V/\sqrt{L}$

(For pin stimulator and sand strip)

Method 11. 1/8″dia × 1/32″ thick, spaced 3/8″ apart along a line 4″ aft of the stem.

Method 12. 1/8″dia × 1/32″ thick, spaced 3/4″ along the contour of the station 1/2.

The results obtained from the experiments, being corrected for the standard temperature 70°F of water, are plotted in the curves of the total resistance coefficient versus the Reynold number and speed-length ratio as shown Fig. 3 and Fig. 4. The former is of sand strips and the later of pins. In Fig. 5 some out of Fig. 2 and Fig. 3 are superposed for the purposes of comparative evaluation of the effectiveness of sand strips and pins.

4. EVALUATION OF THE RESULTS

PINS :

1) Method (6) presents generally good results, however, at $V/\sqrt{L}=0.45$ and lower, this method does not seem to be effective.
2) At $V/\sqrt{L}=0.55$ and higher, method (7), (8) and (9) show the identical results, but at the below $V/\sqrt{L}=0.55$ appears to fail in effective stimulation.
3) Method (10), (11) and (12) are encountered in achieving identical results with method (7), (8) and (9) at $V/\sqrt{L}=0.9$ and higher.

SAND STRIPS :

1) At $V/\sqrt{L}=0.4$ and lower, method (5) shows the better results than the method (3) and (4), however, at $V/\sqrt{L}=0.4$ and higher insufficient for the complete turbulence.
2) Method (3), (4) and (2) show the identical results at $V/\sqrt{L}=0.91$ and higher.
3) Method (1) presents generally good results, however, at $V/\sqrt{L}=0.75$ and higher shows the excessive stimulator drag.

Observing all of the methods carried out in this experiment, method (1) seems to be the most optimum stimulation method for four feet medel at $V/\sqrt{L}=0.75$ and lower. However, at $V/\sqrt{L}=0.75$ and higher this method is not suitable for good turbulence due to the excessive stimulator drag. Method (2) presents generally good results and is encountered in achieving identical results with pin method (6) at $V/\sqrt{L}=0.92$ and higher.

5. CONCLUSION

From the above evaluation of the results of this experiment the following conclusions are derived:

1. At $V/\sqrt{L}=0.75$ and lower, method (1) of sand strip presents the most optimum stimulation method and in the low Reynolds number, two sand strips are required as an activator of the turbulent flow.
2. For both cases of $V/\sqrt{L}=0.75$ and higher, and $V/\sqrt{L}=0.92$ and lower, method (2) of sand strip shows the effective stimulation.
3. In case of pin stimulator, method (6) shows the effective stimulation at $V/\sqrt{L}=0.92$ and higher.

Particularly in case of bare hull, it is remarkable fact that C_t values are lower than C_f values by Schoenherr formula in the low Reynolds number, hence it imports us to know the effective stimulation method in the range of low speed.

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