# 반류조절 Fin의 추진특성에 관한 연구

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# A Study on the Propulsive Characteristics of Wake-Control-Fin

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## 국문요약

본 논문은 지금까지 알려진 추진효율향상을 꾀할수 있는 에너지절감장치들을 정리하여 보고, 그들의 기능과 원리에 대해서 간략히 서술하고자 한다. 그리고, 새로운 에너지절감장치의 하나로서 선체효율과 상대회전효율을 증진시키는 반류조절핀의 개발을 위하여 그 추진특성을 살펴보고자 한다. 이 장치는 빌지와동을 조절하고 부가추력을 발생시키며 프로펠러상부로 흘러들어오는 저속의 흐름을 가속시켜주는 역활을 하는 것으로 판단된다. 이 장치를 9만 5천톤급의 탱커선형에 적용하였으며, 그 추진특성을 확인하기 위하여 4개의 모형을 설계, 제작하여 모형시험을 수행하였다. 그 결과로서 약 1%정도의 연료절감효과를 확인할 수 있었다.

## Abstract

This paper reviews the energy saving devices(ESD) as unconventional propulsors with the corresponding efficiency gains reported. And their functions and principles are described.

This paper presents the propulsive characteristics of Wake-Control-Fin(WCF) as an new energy

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saving device, which is one of propulsors to improve hull efficiency or relative-rotative efficiency. It is expected to control the bilge vortexes and generate the additional thrust and accelerate the retarded flow of upper part of a propeller plane.

The WCF was adopted for a 95K Tanker. Four WCF models were designed and tested to confirm the propulsive characteristics of WCF, yielding fuel savings of about 1.0%.

## Nomenclature

$C_B$ : Block coefficient
$P_E$ : Effective power
$P_D$ : Delivered power at propeller
$t$ : Thrust deduction fraction
$w_s$ : Taylor wake fraction of ship
$\eta_H$ : Hull efficiency$\left(\frac{1-t}{1-w_s}\right)$
$\eta_R$ : Relative rotative efficiency
$\eta_O$ : Propeller open-water efficiency
$\eta_D$ : Propulsive efficiency$(P_E/P_D)$

## 1. Introduction

Nowadays, a lot of energy saving devices(ESD) for ships have been developted by many hydrodynamists in the field of ship design. Some of these devices are known to save the energy in the order of magnitude of 10 to 15%. For well designed ships, however, savings are smaller. They range from 0 to 7%.

Schneekluth[1] introduces several energy saving devices and their principles.

Stierman etc.[2] described the hydrodynamic principles of Schneekluth's wake equalizing duct and Nonnecke's asymmetric stern and applied the former to a product carrier of 84,000 DWT. And the model test results show an improvement of 5 to 7%.

Mewis etc.[3] has developed the SVA fins to reduce the propulsion energy required by ships and to improve the water flow to the propeller. It yields an energy saving of between 4 and 9% when applied to conventional merchant ships.

Energy Saving Devices as unconventional propulsors was reviewed in the 19th ITTC Report[4]. The report is summarized briefly here. The performance attribute of interest is the predicted and measured propulsive efficiency gain due to their use. The criteria for inclusion in this survey is whether the feature or configuration is related to the hydrodynamics of ship propulsors. The various propulsors and propulsor features are listed in Table 1 with the corresponding efficiency gains reported. Reviews have been given by van Beek(1985), Pashin(1986), Glover(1987), Osborne(1987) and Kanevsky(1989) on hydrodynamic principles of operation and estimations of possible efficiency improvements. The compiled data in the Table 1 should be used with care since there are many factors that will affect the accuracy. For example : since the Reynolds number based on chord is typically very low in model tests, significant unaccounted-for sclae effects may be present ; the performance of the reference propeller may not have been optimum or even adequately described; and the ship trial conditions may have changed in addition to the installation of the efficiency improving feature. And the report concluded about the ESD as following ;

– Unconventional propulsors can improve efficiency relative to a conventional single propeller. The success of many of these configurations is based on the recovery of rotational energy shed behind the propeller and/or their modification of flows domanated by viscous effects.

– Model tests at the very low Reynolds number cause significant scaling problems. Both modified test techniques and more powerful numerical methods are required to reduce reliance on semi-empirical scaling.

Table 1. Comparison of unconventional propulsor performance with efficiency as claimed

| Propulsor Type | | Energy Saving Efficiency(%) | |
|---|---|---|---|
| | | Cal. or Model test results | Full scale test results |
| Low RPM propeller | | 5~18 | |
| Coaxial contrarotating propellers | | 7~20 | 15, 16 |
| Propeller with a free-rotating vane wheel | | 8~12 | 6~8.5 |
| Ducted propeller | Axisymmetric duct | 5~20 | |
| | Asymmetric duct | less than Axisym. duct | |
| | Duct in front of propeller | 5~12 | 5 |
| Preswirl devices | Radial reaction fins | 3~8 | 7~8 |
| | Asymmetric stern | 1~9 | |
| Postswirl devices | Add. thrust fins at rudder | 1~8 | 8~9 |
| | Rudder bulb with fins | 1~3 | 4 |
| | Fin on propeller fairwater | 3~7 | |
| Flow smoothing device | Wake equalizing duct | 5~7 | |
| | Guide vanes | 2~10 | 5~10 |

A large number of energy saving devices are grouped from its functions and principles. They can be categorized into two groups and their mechanism is as follows[5] :

(1) improvement of its own efficiency(propulsor efficiency)
  – reduction of propulsor loading
  – reduction of viscous resistance
  – reduction of rotational energy loss

(2) improvement of hull efficiency or relative-rotative efficiency
- minimization of stern flow separation
- control of bilge vortexes
- generation of the thrust by a fin or a duct supported by a propeller
- acceleration of the retarded flow of upper part of a propeller plane

The feasibility of each device is dependent on the fuel saving expected and the costs for realisation(design, licence, model tests, manufacture, fitting). Since the fuel costs decreased in the begining of 1986 it is very important that the realisation costs are kept as low as possible. A pay back period of five years is often considered already too high to decide positively for application of a device.

In this paper the effect of Wake-Control-Fin as a new ESD on the propulsive efficiency is studied and described. It is one of propulsors to improve hull efficiency or relative-rotative efficiency, which controls the bilge vortexes and generates the additional thrust and accelerates the retarded flow of upper part of a propeller plane.

## 2. Wake-Control-Fin

The WCF was developed mainly to improve hull efficiency or relative-rotative efficiency, which has the following three effects which reduce the propulsion power required :
- control of bilge vortexes
- generation of the additional thrust by a fin
- acceleration of the retarded flow of upper part of a propeller plane

The WCF was designed purely on base of the potential flow calculation[6] and the experience by studying the hull form lines and propulsion characteristics. The typical section of WCF is the section of NACA 64.

Two kinds of WCF were designed to control the flow into the propeller plane. The lower fin is fitted near the port-side stern bulb in front of the propeller, which is expected to control the direction of the flow including the bilge vortex. The upper fin is fitted near the both sides of the upper part in front of propeller, which is expected to generate the additional thrust and accelerate the retarded flow of upper part of a propeller plane.

The WCF was adopted for a 95K Tanker with main particulars as given in Table 2 and a body plan according to Figure 1.

Table 2. Main Particulars of the Ship and Propeller

| | |
|---|---|
| **Ship** | |
| Length between perpendiculars | 233.0m |
| Breadth | 41.8m |
| Draft | 12.2m |
| Displacement volume | 95,872$m^3$ |
| $C_B$ | 0.8063 |
| **Propeller** | |
| Diameter | 6.850m |
| Pitch-diameter ratio | 0.704 |
| Expended blade area ratio | 0.524 |
| Number of blades | 4 |
| Section type | NACA 66 |

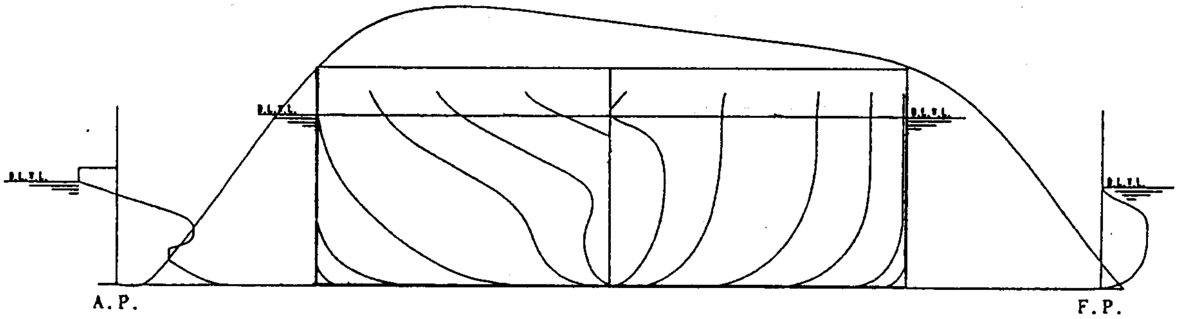

Fig. 1 Body Plan and Curve of Sectional Areas

Four WCF models(WCF-#1, WCF-#2, WCF-A, WCF-B) were designed and shown in Fig. 2. And the ship model with them is shown in Fig. 3.

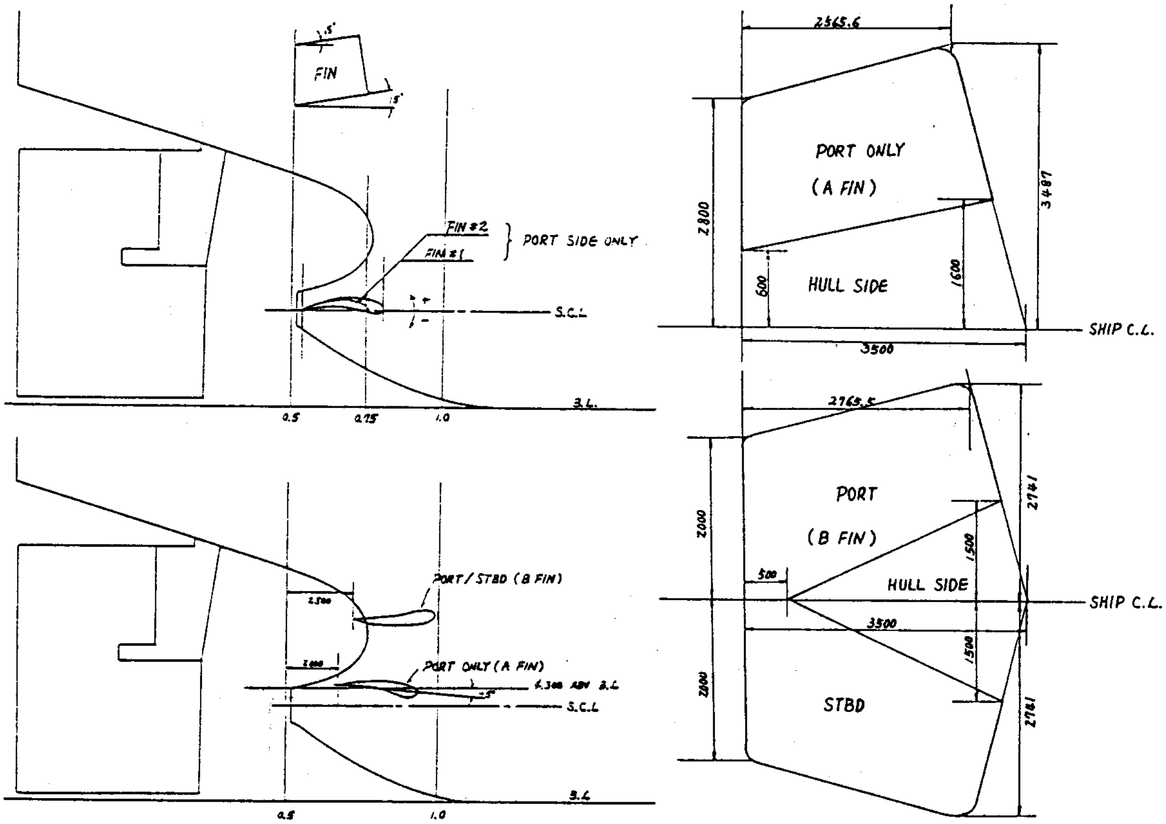

Fig. 2 Configuration of Wake-Control-Fins( #1, #2, A, B)

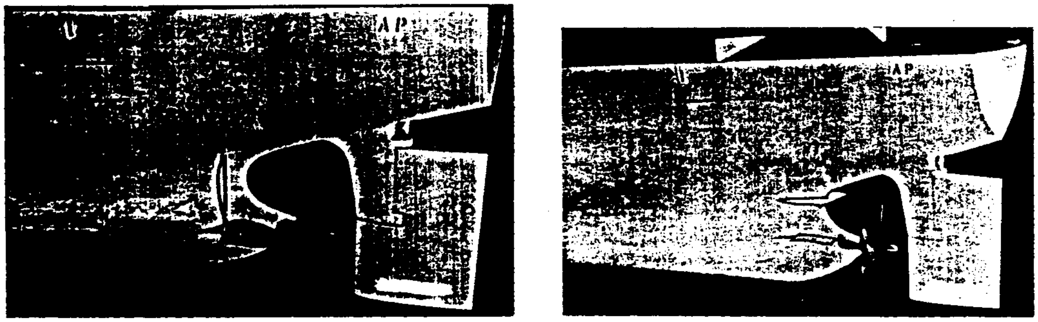

Fig. 3 Photographs of Ship Model with the Wake-Control-Fin
(Left : WCF-#1, Right : WCF-A & B)

## 3. Discussion of Test Results

A series of model tests with the WCF models was conducted to investigate the effect of WCF at the experimental towing tank of KRISO. Based on the Froude's method, the full scale values are predicted from the model test results. The ITTC 1957 Model-Ship Correlation Line is used as an extrapolator. The scale effect correction is carried out based on the 1978 ITTC Performance Prediction Method.

The prediction of the powering performances at the speed of 15.0 knots for the 95K Tanker with Wake Control Fins are summarized in Table 3.

Table 3. Comparison of Powering(Design Load, 15 knots)

| WCF | Angle(°) | $t$ | $w_S$ | $\eta_H$ | $\eta_R$ | $\eta_O$ | $\eta_D$ | $\Delta P_D$(%) |
|---|---|---|---|---|---|---|---|---|
| without | – | 0.220 | 0.327 | 1.159 | 1.022 | 0.598 | 0.708 | base |
| WCF #1 | 0 | 0.240 | 0.345 | 1.161 | 1.017 | 0.585 | 0.690 | +2.5 |
|  | −5 | 0.235 | 0.342 | 1.163 | 1.017 | 0.587 | 0.695 | +1.9 |
|  | +5 | 0.250 | 0.360 | 1.172 | 1.020 | 0.576 | 0.688 | +2.9 |
| WCF #2 | 0 | 0.260 | 0.357 | 1.151 | 1.020 | 0.575 | 0.675 | +4.9 |
|  | −5 | 0.240 | 0.346 | 1.163 | 1.020 | 0.584 | 0.693 | +2.2 |
|  | +5 | 0.260 | 0.366 | 1.167 | 1.011 | 0.571 | 0.673 | +5.1 |
| WCF-B | −2 | 0.213 | 0.311 | 1.142 | 1.022 | 0.603 | 0.704 | +0.5 |
|  | +8 | 0.213 | 0.323 | 1.162 | 1.026 | 0.600 | 0.715 | −1.0 |
| WCF-A & B | A : −5, B : +8 | 0.210 | 0.325 | 1.170 | 1.021 | 0.600 | 0.716 | −1.1 |
|  | A : −5, B : −2 | 0.200 | 0.307 | 1.155 | 1.018 | 0.606 | 0.713 | −0.7 |
|  | A : −5, B : −5 | 0.205 | 0.309 | 1.151 | 1.018 | 0.605 | 0.709 | −0.1 |
|  | A : −5, B : 0 | 0.210 | 0.316 | 1.154 | 1.020 | 0.602 | 0.709 | −0.2 |

(1) It was confirmed through the resistance tests that the variation of the resistance characteristics was negligible in spite of attaching the WCFs to the ship model.

(2) In general, WCF-#1, #2 didn't show the improvement of propulsive efficiency. However, both of the them at the angle of −5° give the least power increment. Judging from these results, it might be failed to control the bilge vortex well.

(3) In general, WCF-A and WCF-B showed the improvement of propulsive efficiency. The 95K Tanker with both WCF-A at −5° angle and WCF B at +8° angle gives the best propulsive efficiency and the achivable energy saving rate is about 1.0%. This improvement is attributed to the reduced thrust coefficient without a significant change in the wake coefficient.

## 4. Concluding Remarks

A Wake-Control-Fin was designed according to the potential theory and the experience, yielding fuel savings of about 1.0%. Though the efficiency of energy saving is small, well designed and positioned WCF can improve it more effectively.

Improvement is mainly attributed to the decrease of thrust deduction fraction and an increase of hull efficiency.

Model test considering the principles of the WCF is necessary to evaluate the efficiency of it precisely.

As mentioned in 19th ITTC, Model tests at the very low Reynolds number cause significant scaling problems. Both modified test techniques and more powerful numerical methods are required to reduce reliance on semi-empirical scaling.

Some sort of experimental flow visualization technique is necessary to design the WCF well and to confirm the effect.

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