EXPERIENCE GAINED WITH CONTAINER SHIPS EQUIPPED WITH SVA FIN SYSTEMS

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ABSTRACT

The Schiffbau-Versuchsanstalt Potsdam (ship model basin) has developed a system of guide 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.

The paper describes some physical considerations leading to the development of the SVA fin system, the effect of which is mainly based on the reduction of losses caused by propeller jet rotation and its consequences and the recovery of boundary flow energy from the broad turbulence field.

Results of tank tests with models of various ship types are presented, and practical experience with the fin system installed on VCS of the "Saturn" class is reported. The trial trip results for the "Saturn" class vessels are in good agreement with those predicted by theoretical analysis and the model tests, and, thus confirm the effect of the fins.

Comparison of the results of the model tests with those obtained with the full scale ship shows that the ship yields a slightly higher energy saving.

SYMBOLS USED

D	[m]	Draught
L_{PP}	[m]	Length between perpendiculars
n	[rpm]	Speed of rotation
P_D	[kW]	Power output at propeller
Q	[Nm]	Propeller torque
T	[N]	Propeller thrust
V	[kn]	Ship speed
Δ	[%]	Change in measured value (negative = reduction)

ABBREVIATIONS USED

Ro/Ro	Roll on - Roll off ship
SPL	Self-polishing paint
SVA	Schiffbau-Versuchsanstalt Potsdam
UCC	Universal container carrier
VCS	Full container ship

INTRODUCTION

During the 15th Jubilee Session in Varna in 1986 [1], a lecture was presented describing a fin system developed by the Schiffbau-Versuchsanstalt to improve the propulsion properties of ships, and the fundamental physical considerations leading to its development were explained. Since then, the SVA fin system has been tested on ships of various types.

The present paper briefly explains the working principles of the system again and reports on some interesting model test results. Furthermore, a detailed report is given of the results obtained during the trial trip of MV "Saturn", a 1166 TEU container ship and the first seagoing ship equipped with the SVA guide fin system.

WORKING PRINCIPLE OF THE SVA FIN SYSTEM

The SVA fin system was developed mainly to achieve two effects which reduce the propulsion power required:

- Generation of a rotating water flow to reduce the losses caused by propeller jet rotation;
- Recovery of energy from the ship's wake by appropriately influencing the water flow to the propeller.

To obtain these effect, the flow guides must be arranged forward of the propeller (cf. Fig. 1).

Thus, the SVA fin system represents a special form of the counterrotating propeller concept, a problem which was discussed in detail by the authors of [2].

The actual design and arrangement of the SVA fin system are based on the following considerations:

The principal factors influencing the arrangement of the flow guide elements are the thrust load and pitch of the propeller and the wake field of the ship. The latter is simultaneously the propeller influx field, and its transversal component is especially important. Depending on the shape of the frames, modern single-screw ships generate the two different types of transversal wake field shown in generalized form in Fig. 2. Owing to their U-shaped framing most modern ships are characterized by a more or less modified U type wake field. The most significant difference between U type and V type wake fields is the large scale eddy associated with the former. This causes reversal of the vertical flow near the ship's side within the propeller disk, so that the flow is directed downwards in this region.

Fig. 3 shows more clearly the very different basic structures of the propeller influx fields of the two wake types. The arrow lengths on the transversal flow lines give an approximate picture of the distance the water flows when passing the last frame spacing forward of the propeller (= 0.05 x L_{pp}) without being influenced by the propeller.

Obviously the U type wake field contains more energy than the V type field. Therefore, more energy can be recovered by the flow guide elements.

The wake field of symmetrical single-screw ships is also symmetrical. This means that the propeller, owing to its rotation, operates under extremely asymmetric flow conditions: on the upward side it follows the upwart flow (over the whole blade radius only in the case of V type fields), and on the downward side it moves against it. Since the influx angles can be as large as 10°, the difference between the two sides of the ship can be as much as 20°. The oblique influx on the downward side is equivalent to "contra-rotation", which is favourable from the energetic point of view, while the "following rotation" on the upward side is energetically unfavourable. The contra-rotation forward of the propeller is superimposed on the rotation generated by the propeller in such a way that the peripheral component, if any, of the jet is small. The following rotation forward of the propeller increases the rotation-induced jet loss. Rotation of the propeller jet and the corresponding losses could be reduced if the following rotation could be eliminated, or even converted into contra-rotation, by a flow guide structure arranged forward of the propeller.

The loss caused by jet rotation can be estimated (cf. [1]) and is reported to be 3 to 4 % in normal single-screw ships. Assuming that jet rotation losses are compensated by the rudder gain, an energy saving in the order of 3 to 4 % of the propulsion power can be expected alone by reducing the rotation component. Ships with a V type wake field do not permit any significant energy saving in excess of this figure. A flow guide fin on the upward moving side will be sufficient, and the effect of such a fin is shown in Fig. 4 in greatly simplified form.

Ships with a U type wake field offer more potential for improvement. Owing to the reversal of the vertical influx in the vicinity o the ship's side, the flow guide structure must unavoidably be more complex, but a greater gain is possible. If a compact fin is fitted forward of the propeller on the upward moving side as provided in the SVA fin system, the leading edge of the fin must be adapted to the actual flow field, i. e. its forward portion must be raised in the vicinity of the ship's side. The effect of such a fin is shown in Fig. 5 in simplified form. The energetically unfavourable flow near the ship's side on which the propeller blades move downwards can be reversed by one or more small guide elements (cf. functional sketch in Fig. 6). Practice has shown that an additional gain of 2 to 4 % can be obtained by this arrangement, even this can be increased by further improvement of the system.

In other words, depending on the type of the ship's wake field, the fin system as it is (i. e. without additional modification of the propeller) can yield energy savings of between 3 and 8 %. A further 1 to 2 % can be saved if the propeller is matched and optimized within the whole system with pre-rotation flow.

MODEL TEST RESULTS

When development began, the efficiency of the fin system was checked only by propulsion tests. Later, wake measurements and cavitation tests were carried out to investigate possible side effects.

The main criterion for the optimization of the fin system during propulsion tests was its effect on the propulsion power required, i. e. in each case the version requiring the least propulsive energy was determined. The parameters used to determine this effect were the measured speed, torque and propeller thrust. A special test procedure was elaborated to permit the measurement of differences in the order of 1 % during these tests (cf. [3]).

Table 1 shows the fin-induced changes in the measured propulsion parameters for some of the ship models tested at the SVA Potsdam. The values were measured on ship models at service speed and design draught. The gain obtained in the studied speed range is almost independent of the speed, whereas some dependence on draught was observed. Experience has shown that the gain at ballast draught with the ship trimmed down by the stern is about two thirds of that obtained at design draught.

Table 1 shows that the gain obtained for the above ship models with the SVA fin system is between 2.6 % and 6.2 %. The gain was smallest for a model of the VCS "Saturn" class vessel, the only ship with a wake field without eddy (V type).

INSTALLATION OF THE SVA FIN SYSTEM ON A "SATURN" CLASS CONTAINER SHIP BUILT AT WARNOW-WERFT WARNEMUENDE

Up to now four ships of the "Saturn" class container ship have been built, the first of them without a fin and three with one fin each. In view of the uncomplicated wake field, the simplest form of the SVA fin system, namely one fin on the port side, was installed as shown in Fig. 4. The ship is equipped with a right-hand propeller, and therefore the fin is fitted to the port side forward of the propeller. As shown in Table 1, the first full-scale test was carried out on a ship with a relatively small potential for energy savings. The "Saturn" class VCS is described in detail in [4] and [5]. The main data of the ship are as follows:

Length between perpendiculars	163.85 m
Breadth	25.40 m
Draught	9.60 m
Deadweight	16760 t
Container carrying capacity	1166 TEU
Rated output (100 %)	12160 kW
Rated speed	130 rpm
Propeller diameter	5.70 m

[6] gives a detailed report on the experience gained with the SVA fin system on this ship. The present paper presents only the most important results of model tests and the trial trip.

The fin was designed in close cooperation between Schiffbau-Versuchsanstalt Potsdam and VEB Warnowwerft Warnemuende with approval by DSRK, and construction work was carried out at the Warnowwerft shipyard.

MODEL TEST RESULTS FOR THE "SATURN" CLASS SHIP

Model tests were carried out under the conditions described in the section "MODEL TEST RESULTS" using various versions of the guide fin at two different draughts to verify the effect of the fin on the model. The results obtained with the final fin are shown versus the speed in Fig. 7.

It is evident from Fig. 7 that the energy saving is practically independent of the speed. The following savings were obtained:

D = 9.60 m, fully loaded ship, V = 19 kn: P_D = 2.6 %

D = 5.90 m, ship in ballast, V = 20 kn: P_D = 2.1 %

The results of the model tests have proved to be reproducable during subsequent tests.

TRIAL TRIP RESULTS OF A "SATURN" CLASS SHIP

It is much more difficult to demonstrate the effects of the fin with a full-scale ship than with a model. A genuine comparison is possible only by performing trial trips at short intervals using the same ship with and without fins, but this is impracticable for technical and financial reasons.

Therefore, the only basis for assessment was a comparison of the trial trip results of the four sister ships, one of them being without a fin and three being equipped with fins. These results reveal the whole problematic nature of comparisons: differences in external conditions during sea trial (painwork, propeller condition, weather conditions, etc.) influence the achievable speed much more than the fin effect. Table 2 shows the most important conditions and the results of the sea trials of the four sister ships. Unfortunately, the first of the three ships with fins was much slower than the one without a fin due to a different pain system and/or subsequently detected fouling of the propeller. But the two other ships with fins started for sea trials under nearly the same conditions as the finless ship and demonstrated a significant positive effect of the fin on maximum achievable speed, a parameter that is measured only during sea trials and which was much higher than predicted on the basis of model tests.

The four sister ships were tested at sea at five engine speeds ranging between 85 rpm and 130 rpm in accordance with an extended sea trial programme to increase the reliability of the data and to test the fin effect over the whole relevant speed range.

Fig. 8 compares the trial trip results of yard no. 183 and 184 and the model test results. It is evident from the graph that the efficiency gain during sea trials was slightly higher than during the model tests. When considering these results, however, it must be borne in mind that sea trial results are influenced by stochastic variables owing to the sometimes undefined conditions during sea trials.

The substantially higher gain at full engine speed can be attributed to the stronger influence of wave resistance and the possible influence of the fin on the wave pattern due to the location of the former relatively close to the water surface in the ballast condition. Filaments with a length of about 20 cm were bonded to the upper side of the fin of yard no. 182 in a reticulate pattern, and observed through windows to check the flow guiding effect of the fin during sea trials. It was seen that the flow is laminar for about 90 % of the profile depth on the fin upper side (cf. [6]). This was confirmed during a bottom survey in drydock after one year of operation. The area rubbed by the filaments was very narrow in general and gave an impression of the direction of the flow.

So far, the guide fins have not induced negative effects such as cavitation, vibration or poor manoeuvrability during sea trials or commercial service.

Up to the present, all tests and trials have fully confirmed the benefits of the fin.

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Table 1:

SVA fin system effects on measured values at design draught and service speed without propeller modification

Ser. no.	Shiptype length	Type of wakefield	No. of fins	% change in measured ΔP_D	Δn	ΔQ	ΔT
1	VCS "Saturn" 164 m	V	1	-2.6	-2.2	-0,4	+0.1
2	UCC 145 m	U	2	-4.5	-2.2	-2.4	-2.0
3	Fishingvessel* 116 m	U	2	-3.1	-1.1	-1.9	+2.7
4	Ro-Ro-ship 170 m	U	2	-5.4	-2.1	-3.3	-3.8
5	Containership 135 m	U	1	-5.0	-2.9	-2.1	-0.3
6	Fishingvessel 153 m	U	2	-6.2	-2.5	-3.8	-3.4
7	Containership* 140 m	U	1	-2.8	-2.4	-0.4	+1.9

Note:
Ships marked with an asterisk are not yet fully optimized or optimization procedures have been terminated. In these cases, the increase in the T value indicates that further improvement is possible.

Table 2:

Sea trials result of "Saturn" class vessels with and without fins

Yard no.	181	182	183	184
Fin	without	installed	installed	installed
Paint coat	SPL	standard	SPL	SPL
Propeller condition	clean	fouled	clean	clean
Date of sea trials	18-5-87	14-9-87	8-6-88	23-4-89
Wind/sea	2/1	0/0	1/1	4/4
Sea trial results converted to standard conditions (engine speed = 130 rpm)				
ΔV [kn] ΔP_D (V = 21 kn) [%]	0 0	-0.58 +9.6	+0.49 -7.6	+0.27 -5.2

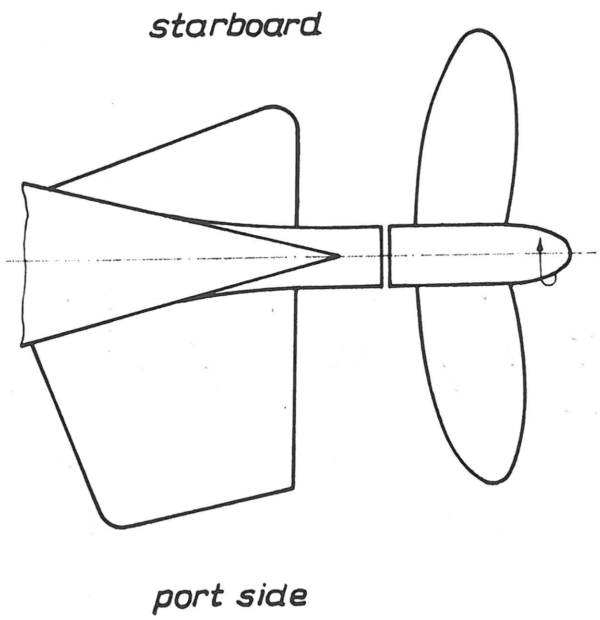

Fig. 1 SVA guide fin system for right-hand propellers
U type wake field
View from above

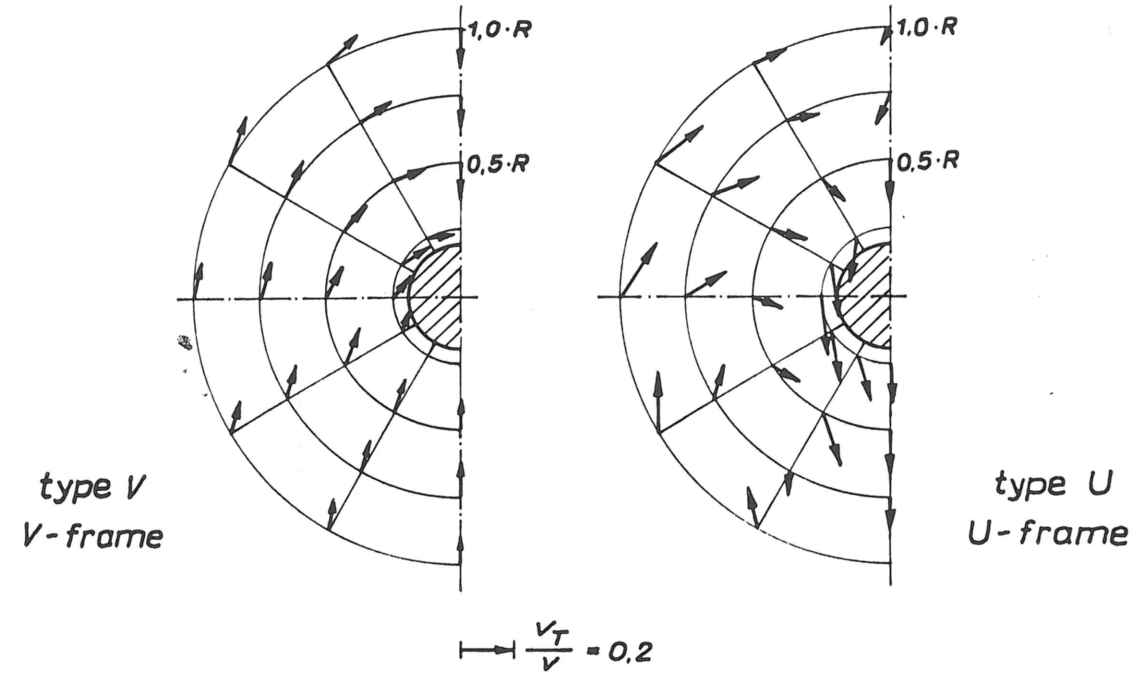

Fig. 2 Transversal components of the nominal wake field in the propeller plane

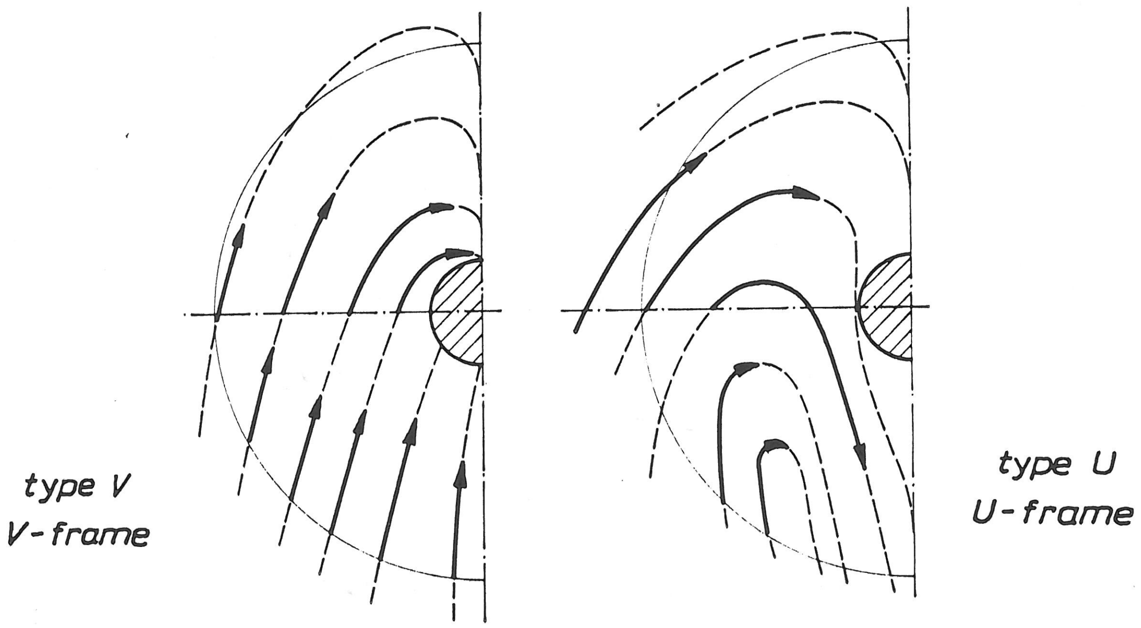

Fig. 3 Flow pattern of the influx to the propeller plane without fins (arrow lengths indicate the distance the water covers when flowing across the last frame spacing (0.05 x Lpp) forward of the propeller).

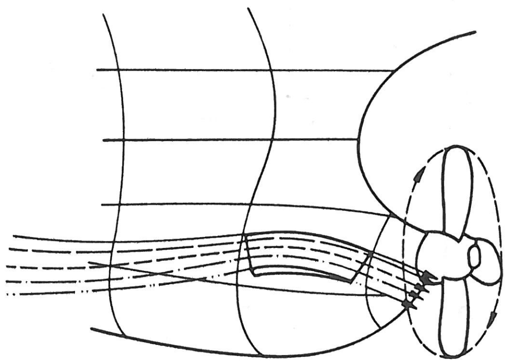

Fig. 4 Working principle of the port fin on a ship with V type framing (simplified)

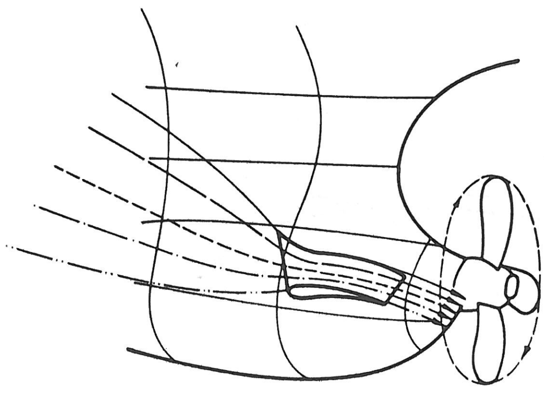

Fig. 5

Working principle of the port fin on a ship with U type framing (simplified)

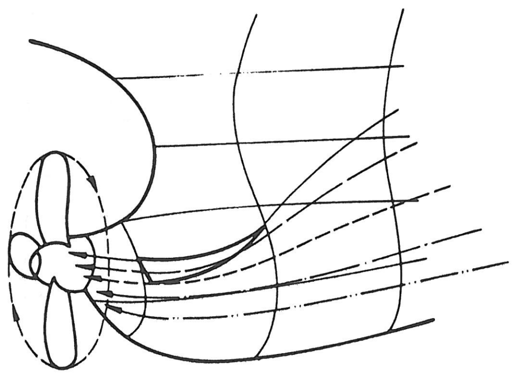

Fig. 6

Working principle of the starboard fin on a ship with U type framing (simplified)

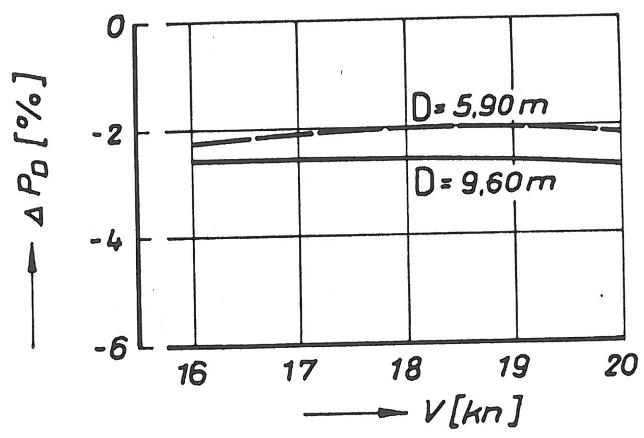

Fig. 7 Energy saving by the SVA fin on a VCS "Saturn" in model tests

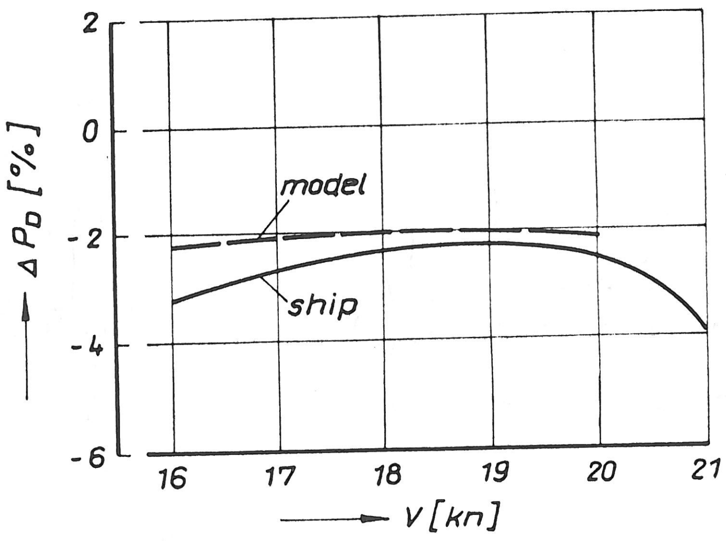

Fig. 8 Energy saving by the SVA fin on a VCS "Saturn" in model tests and during sea trials
T = 5.90 m; 1.7 m down by the stern