Devices improving the manoeuvrability characteristics of ships

Part II
”Doerffer’s Rudder” – experience learnt from tests carried out on real ships

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ABSTRACT

An account of research activities on the devices improving the manoeuvring abilities carried out at the Gdansk University of Technology were presented in Part I of the paper. Experience from implementation of open rudders on real ships is presented in Part II. Open rudders were fitted on two full size ships: a 1000 BHP harbour tug and a 2500 BHP long line fishing vessel. Designs were made for four types of ships: motor sailing passenger ship “Gwarek” (2 x 1.032 BHP and 1800 m² sail area); arctic expedition sailing ship m/y “Polarex” (length 40,4 m, 1200 BHP); rescue vessel R-27 (two engines à 600 BHP with single propeller); harbour tug m/t “Atlas” (2500 BHP). None of these designs was implemented due to financial difficulties of the owners. Further model experiments with a self propelled model of a cargo liner m/s “Hollandia” exceeding 20 knots were carried out on the lake as well as with a model of a twin screw vessel.

Keywords : the results of tests with „Doerffer’s Rudder”, opening balbous bow, opening rudder, stern shield, steering braking device, braking the ship

INTRODUCTION

The results of tests with “Doerffer’s Rudder” carried out in cavitation tunnel and with models in towing tank have shown great merits of this device. A decision was taken to implement this device on a full size ship and to prove its applicability in real working conditions of a ship. First of all it was necessary to find a ship of very poor manoeuvring characteristics which could be used for the experiments and later on could be returned to service to see the merits of this device in every day life. That ship should have be easily accesible to the designers in order to make some improvements in the design or to carry out any repairs. Our first choice was a 24 years old harbour tug “Achilles” of very low manoeuvring characteristics, which was meant to be scrapped in few years time. In case the new rudder was a failure she could be scrapped with no great loss. The second vessel chosen for installation of “Doerffer’s Rudder” was a deep sea fishing trawler m/t “Kolen”.

HARBOUR TUG “ACHILLES”

The only change that was introduced in the rudder of “Achilles” was the limitation of angles of opening of blades from +110°/-40° to +75°/-25°. For conventional steering the rudder blades could be blocked and activated with one power unit and for braking they should be opened symmetrically to an angle of 75°. When the rudder blades were opened to an angle of 48° the resultant thrust i.e. the difference between the propeller forward thrust and the force induced by the propeller wake on the opened rudder was equal to zero. Decreasing this angle below 48° gives a gently increasing resultant force forward, while increasing this angle above 48° gives the resultant force acting aft and the ship begins to move aft. This gives a possibility to start the main engine with the rudder opened to an angle of 48° and to obtain half or full revolutions ahead, while the ship is moored at the dock side.

The steering column contains two hand levers for setting the desired angle of opening of each blade and there are two pointers indicating the actual position of each blade. Two steering systems are provided :

⇨ a follow-up system, automatically setting the blade to the desired angle as indicated by the position of the lever
⇨ a press button system, activating respective power unit of a steering engine in required direction as long as the button is being pressed.

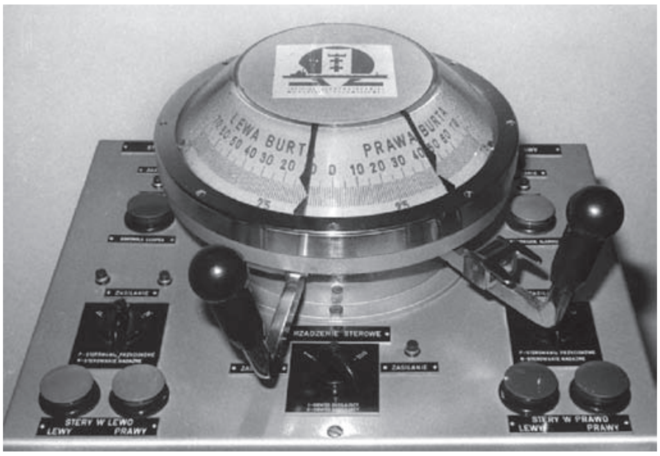

Fig.1. *Photo of “Achilles” steering column.*

Normally the first system is being used and the second system is considered as an emergency procedure. An additional emergency hand steering system is provided.

The results of tests have shown the following results :

✦ The speed of the ship has been slightly increased – service speed increased from 10.23 knots to 10.46 knots (curve [1] to curve [2] – Fig. 2). There exists a possibility of continuous regulation of speed from maximum forward to maximum astern with constant revolutions forward of the main engine through varying the angle of opening the blades (curve [3]), what is done by the skipper from the bridge. At the angle of 48° of opening the blades the resultant force is zero and the ship remains stationary despite the main engine working at full revolutions forward

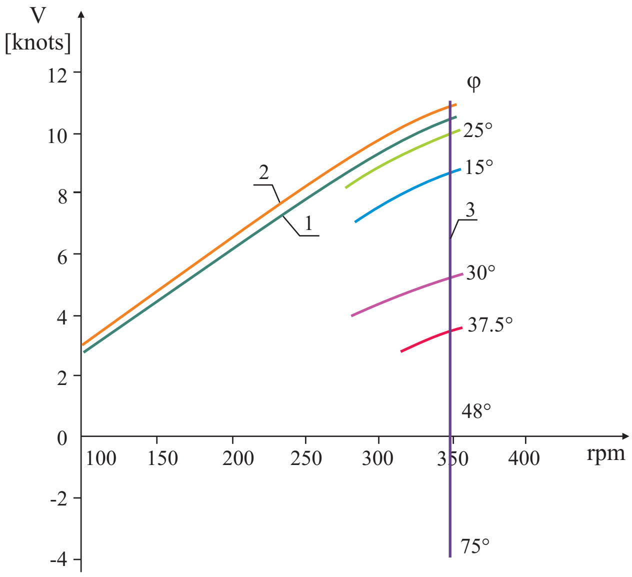

***Fig. 2.** Speed versus revolutions of "Achilles" main engine.*

- turning ability with blocked blades and activated by one steering power unit to 25° P & S at full, half and slow speeds has shown slightly larger diameters of circulation, this being due to higher initial speed of the ship. When a smaller diameter of circulation was required than the blades should be freed and larger angles applied. The ship is capable of rotating in place around her bow when one blade is opened to 75° and the other one to 25° in the same direction, making one full turn within 80 seconds
- stopping test has been carried out with blocked rudder blades by reversing the propeller and with rudder blades opening to an angle 75°/75°. The stopping distance was 145 m as against 198 m what means shortening of stopping distance by 36.5 %
- bollard pull forward (Fig. 3) has increased by 15% with the new rudder [2] and astern pull with reversed engine by 20% [5]. With opened angle 75°/75° and the engine running forward the astern pull [5] amounted to 4 tons (about 80% of pull with balanced rudder and reversed revolutions of main engine)

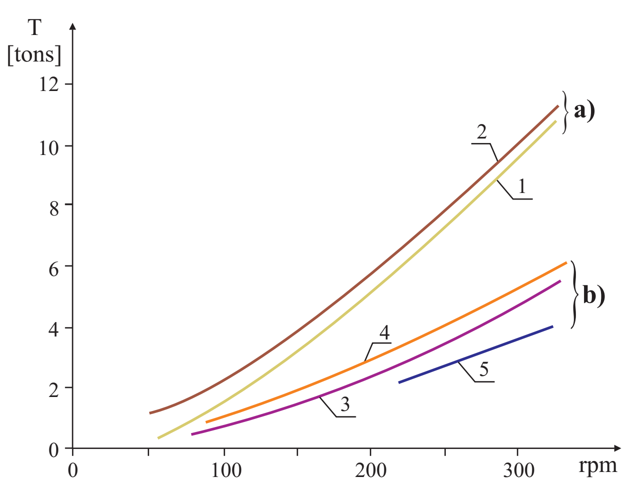

***Fig. 3.** Bollard pull forward and astern of "Achilles".*

- transverse thrust at zero speed could be easily obtained by appropriate opening the rudder blades. By asymmetric opening the rudder blades to angle 45°/-20°at 350 rpm a very powerful transverse thrust was created up to 7.0 tons through the propeller stream emerging to one side only. Thus the rudder can act as a powerful stern side thruster
- the reliability of all the manoeuvres is enhanced with the engine running all the time without stopping and reversing/restarting the main engine
- no vibrations during stopping ad astern running
- cheaper maintenance of main engine due to running under steady parameters.

Opening rudder has shown many advantages in full size application. It has shown that it could be easily applied on existing ships and radically change manoeuvring characteristics. The only disadvantage was the increase of daily fuel consumption. This was due to running the engine all the time even when waiting at the dock side. The tug was working successfully for several years, but finally had to be scrapped due to corrosion of the hull.

The above results are spectacular and this is because of the very high ratio of installed main engine power to displacement of this harbour tug which is equal to 4.0. Dry cargo ships have generally this ratio not exceeding 0.3 and some large tankers have even below 0.1. As the effects of this rudder are connected with this ratio, the application of "Doerffer's Rudder" on such vessels will give very good results but not as spectacular. Apart from considerable improvement in manoeuvring characteristics of large dry cargo ships and tankers there should be considerable fuel savings, reliability of main engine installation should be improved, maintenance costs should be lowered and break down limited.

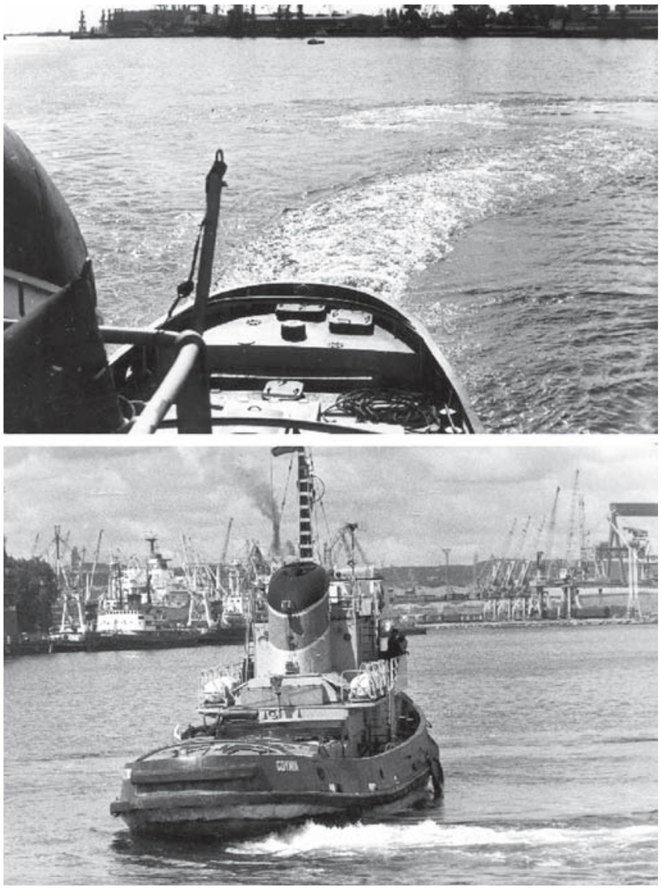

***Fig. 4.** Photo of Tug "Achilles" showing her manoeuvring ability and producing transverse force.*

FISHING TRAWLER M/T "KOLEN" AND OTHER PROJECTS

The second vessel chosen for installation of "Doerffer's Rudder" was a deep sea fishing trawler m/t "Kolen" which had to be adapted for long line fishing. For this method of fishing smaller vessels were being used, generally not exceeding 50 m length with very good manoeuvrability. But m/t "Kolen" was 75.5 m long and the main engine was 2500 BHP (Fig. 5).

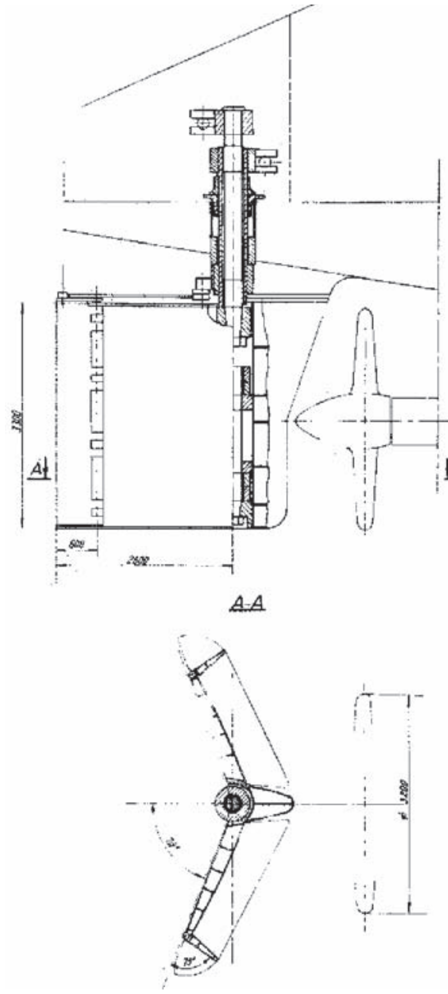

Fig.5. *Stern frame and opening rudder of m/t "Koleń".*

The stern frame had no heel supporting the rudder at its bottom end. So a special rudder front support had to be designed and built into the ship structure with a possibility of dismantling this bottom part in order to make the propeller and tail shaft dismantling possible for repairs. The ship with after being equipped opening rudder, demonstrated excellent manoeuvring characteristics and it was working successfully on the Atlantic.

There were also ship owners of special purpose ships who ordered the designs of opening rudder for their ships – the ships were :

★ motor sailing passenger ship s/y "Gwarek" (212 passengers, 1800 m² sail area, length 99 m, main engines 2 x 1032 BHP) (Fig. 6). The ship has been fully fitted with opening rudder, but before final completion the owner declared bankruptcy and after some years a Swedish owner bought that uncompleted vessel, lengthened her and completed as a luxury sailing ship. He demanded to have a well known simple balance rudder because of the high underwriting costs in case having a rudder of unknown type.

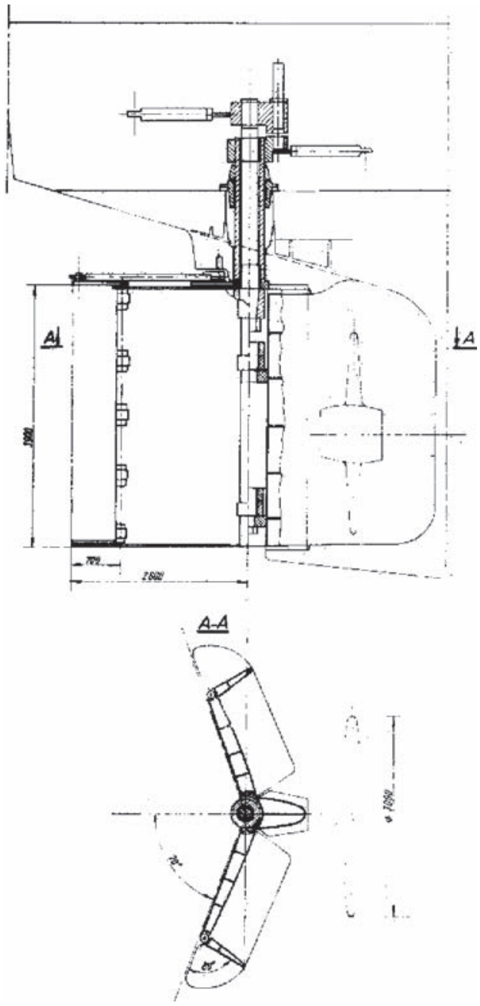

Fig.6. *Stern frame and opening rudder s/y "Gwarek".*

★ arctic expedition sailing ship m/y "Polarex" (length 40,4 m, 1200 BHP). Design has been completed, but again the owner declared bankruptcy after the launching of the ship. The hull has bought by Maritime Academy in Gdynia, the ship has been lengthened and completed as a training vessel. It should be mentioned that before the design was made extensive ice braking trails were made with the tug "Achilles", which have shown exceptional ice breaking abilities. These were due to very high transverse side thrust obtained with opened rudder which could be easily obtained by opening the rudder several times to P and then to S. Powerful transverse force one after the other acted in the similar way as the carpenter trying to free the wedge not by pulling it out but by several knocks from the side. The emerging wake cleared the water from ice floes.

★ Polish Salvage Company had four rescue vessels R-27. These ships had two 600 BHP diesel engines working through reduction gearing on one propeller. The gearing was of very complicated design and was easily breaking down. This was unacceptable for a rescue vessel. Thus we were asked to design an opening rudder which would allow simplifying the reduction gearing and improving the manoeuvring characteristics of the ship. The design was completed, but the owners got a possibility of replacing the old reduction gearing by a new one and they have decided to purchase the gearing. And thus our design was not implemented.

SHIPS WITH SPEED ABOVE 20 KNOTS

Despite all the difficulties we had in full size implementation of opening rudder we continued our research on application of this rudder on ships with speeds above 20 knots. First question asked by any owner was the problem of increase in resistance of the ship due to new type of the rudder and possible increase in power requirement to maintain the speed before new rudder was fitted. The second question concerned the benefit from increased manoeuvrability. In order to answer these two questions we had to carry out several trials with radio controlled self propelled large scale models in model tank as well as on a lake at Joniny (Wdzydze Lake). These trials gave encouraging results, but it's difficult to state whether model tests will be fully confirmed by a full size implementation. They can be treated as an indication that we are on the right way but the actual values obtained with a ship may differ from the values obtained on a ship model. After long discussions, the open water trajectory experiments were carried out on the lake at Joniny with a model of a containership m/s "Hollandia" of dimensions given in Tab. 6.

Trajectories of circulation were worked out for initial speed of 1.93 m/s, and different angles of opening 70°/-40°; 70°/-25° and 45°/-25°. For initial speeds 1.50 m/s and 0.00 m/s only one opening of blades was experimented with (Fig. 7).

Tab. 6. *Containership m/s "Hollandia".*

Item			Ship	Model
Length between perpendiculars	L_{PP}	[m]	193.10	6.4367
Length on waterline	L_{WL}	[m]	196.78	6.5593
Breadth	B	[m]	30.80	1.0267
Draft: Forward	T_F	[m]	9.20	0.3067
Aft	T_A	[m]	9.20	0.3067
Displacement		[m³]	32211	1.193
Wetted Surface		[m²]	6566	7.2957
Block coefficient CB			0.589	
Model Scale			**1:30**	

Trajectories of braking the ship model were worked out for three initial speeds of the model: 1.50 m/s, 1.00 m/s and 0.00 m/s and for three different angles of rudder symmetrical opening: 50°/50°; 65°/65° and 80°/80°. From Fig. 8 it can be seen that the model running with initial speed 1.50 m/s with rudder blades opened to 80°/80° after 30 seconds looses its forward speed, begins to move astern and looses control of the course.

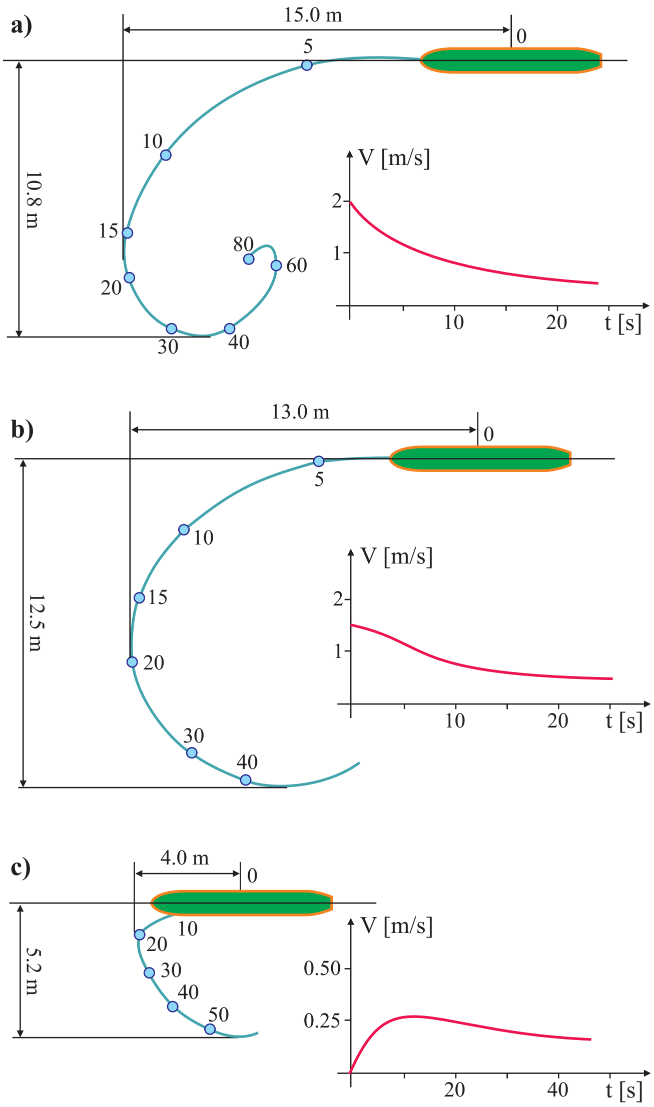

Fig. 7. *Trajectories of circulation for initial model speed:* ***a)*** *1.93 m/s,* ***b)*** *1.50 m/s and* ***c)*** *0.00 m/s and one angle of opening the blades: 70°/-40°.*

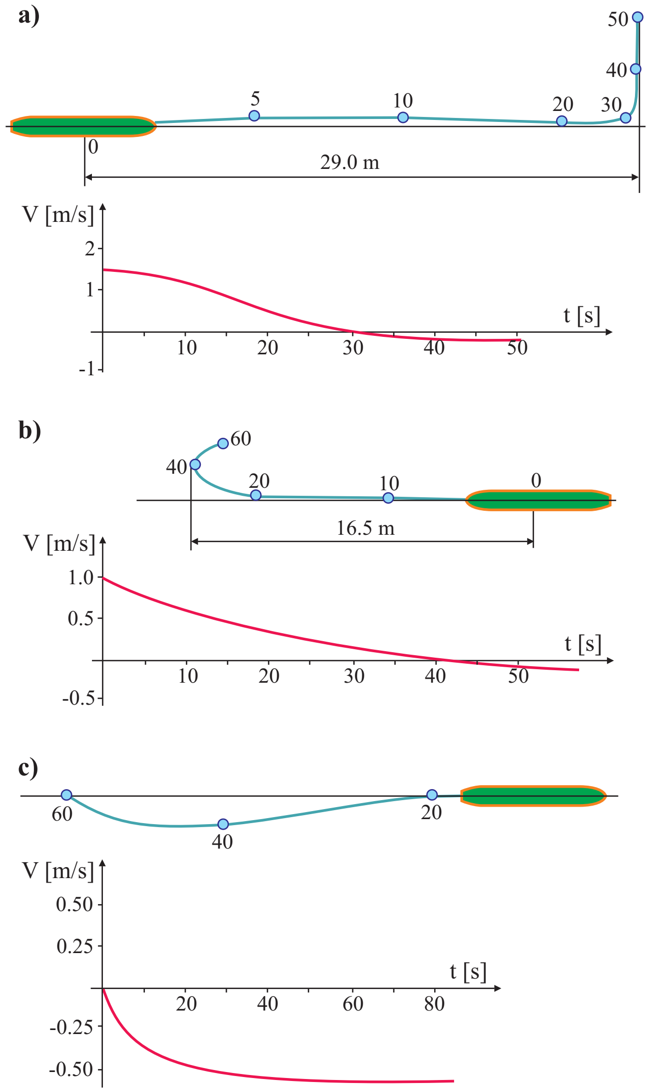

Fig. 8. *Trajectories of braking the ship model with initial speeds of model:* ***a)*** *1.50 m/s,* ***b)*** *1.00 m/s and* ***c)*** *0.00 m/s and for one angle of rudder symmetrical opening 80°/80°.*

TWIN SCREW SHIPS

For the purpose of testing a twin screw ship, existing model was used and was fitted with two balance rudders and alternately with two "Doerffer's Rudders". It was a model of a ship of length L_{WL} = 148.85 m in scale 1:20. The resistance tests have shown that the model fitted with two "Doerffer's Rudders" had at the speed of 16 knots an increase in resistance by 6.5% as compared with ordinary balance rudders which lowered the service speed by 0.5 knot. But these rudders improved the manoeuvrability especially at low and harbour speeds. Opening of rudder blades and flaps and both propellers working forward created an astern pull amounting to about 40% of forward thrust at service speed. This fact allowed to reach the astern speed amounting to about 35% the astern speed with reversed propellers i. e. about 5 knots with both propellers working forward. This astern thrust allows the shortening of braking distance with a full course control by 35%. When the blades and flaps are opened to appropriate angles the ship circulates with a zero diameter of circulation.

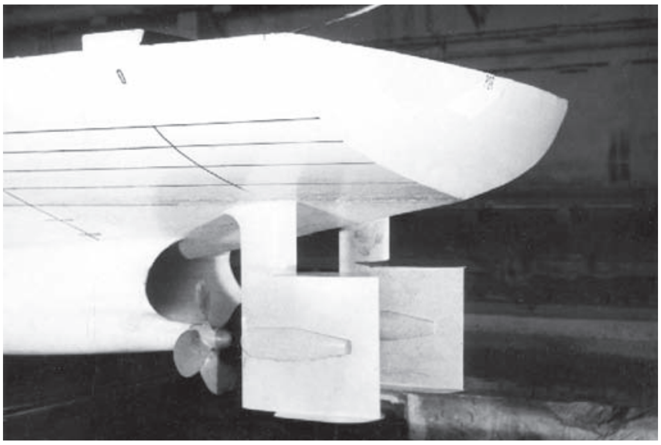

Fig. 9. *Photo of tween screw stern model*

These tests have clearly shown that the owner has to make a choice between the service speed and manoeuvrability, based on what is more economical for him. Poor manoeuvrability may mean hiring the tugs at each harbour entrance, losses in time waiting for tugs or weather to improve. Slower steaming by 0.5 knot may be of no great importance.

CONCLUDING REMARKS

The results of the model tests with "Doerffer's Rudder" carried out in the cavitation tunnel and in the towing tank have demonstrated significant and multiple positive effects of the device on manoeuvrability characteristics of ships.

Full size ship trials performed on real vessels – a harbour tug and a fishing trawler – confirmed the model test results in real working conditions.

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Abilities of contemporary tugboats, photo: Cezary Spigarski