Rapport No. 293

LABORATORIUM VOOR SCHEEPSBOUWKUNDE

TECHNISCHE HOGESCHOOL DELFT

Visualization of the effect of some turbulence stimulators

by

Ir. J.J. van den Bosch

and

Ir. J.A. Pinkster

january 1971.

Contents

1. Summary

A description is given of dye tests carried out with a model of a sailing yacht to compare the effect of a number of turbulence-stimulator devices. Results of the tests are given in the form of photographs of the observed flow phenomena in the boundary-layer of the model.

2. Introduction

In the past a large number of types of turbulence stimulating devices for use in ship-model testing has been tried, the effectiveness of such devices being mostly judged by the trend and scatter of the restistance coefficients at low speeds. On the larger models these stimulators have , on the whole, been shown to perform satisfactorily at speeds over 0.6 m/sec.
At the first tests conducted at the model basin of the Delft Shipbuilding Laboratory with a 1.40 m LWL model of a sailing yacht (mod. 87) to determine the value of lateral force and resistance by oblique towing, results were produced which indicated inconsistenties in the characteristics of the flow around the model. The turbulence stimulation device on this model consisted of a 1 cm sand-strip along the forefoot and keel. To ascertain the resistance of the sand-strip itself, the tests were repeated with a sand-strip of 2 cm. A comparison of the results showed a considerable discrepancy in the values of the lateral force. As the model was fitted with a keel of airfoil section (NACA 0010), of considerable lateral area, the conclusion that the differences in lateral force were due to breakdown of the flow-pattern along the keel was considered justified.
Suspicion being aroused a review of existing publications on this subject was made, the most important conclusions being :

-Laminar flow is very persistent on the fore part of models with V - sections and cut-away forefoot. A negative pressure gradient in the flow direction tends to stabilize laminar flow in the boundary layer.

-Turbulence stimulation devices like tripping wires, closely packed sand-strips, or rows of closely placed studs, which have their largest dimension perpendicular to the flow along the surface, tend to induce local separation.

-Single angular protuberances of about the same height as the local boundary layer seemed to be most effective as stimulators.

-There appeared to be no conclusive evidence that methods to increase the degree of turbulence ahead of the model, like rods or waterjets, had a desirable effect. Also the practise to minimize the waiting time between runs was advocated by some and rejected by others. Rotating rods, introduced by Kulkarni showed some promise.

These conclusions were not decisive, and it was decided that the visualization of the boundary layer flow should be attempted, using different types of turbulence stimulator on the same sailing-yacht model.

3. Description of the experiments

3.1. Choice of stimulator types.

An important consideration was the desire that the stimulator could be fitted with a minimum of delay.
The following types were chosen.

a. Studs

These were of the cylindrical type with a diameter of 3 mm and a height of 2.5 mm. The placing of the studs is shown in figure 1.

b. Sandstrips

These were made of grains of carborundum size 020, the number of grains per sq.cm being only about four. It was thought that widely spaced grains are fully effective as three-dimensional stimulators, and do not retard the boundary-layer too much, which is of particular importance with respect to the fin keel.
The sandstrips were applied after the tests with the studs. Because of the things learned from these first tests the sandstrips were not fitted along the stem but as shown in figure 2.

c. Rotating rods

Two rods; with a diameter of 3 mm, and set with small pieces of wire, with a diameter of 1 mm and about 2 mm long, were placed 15 mm apart. They could be rotated in opposite directions. With a high number of revolutions an intensely turbulent field was created in the direct environment of the rods. As the rods were placed ahead of the model it was deemed necessary to determine the velocity in the wake of the rods. Measurements of the wake velocity were carried out at a distance of 0.65 m downstream of the rods. The results of these measurements are shown in figure 4. It is noteworthy, that the wake-fraction proved to be practically independent of the forward speed and the speed of rotation.
The relatively high values of the wake-fraction obtained may be considered as a serious impediment in the use of this device.
The positioning of the rods is shown in figure 3.

3.2. Observation of the flow-pattern

Observation of the flow-pattern in the boundary-layer was made possible by the injection of a potassium permanganate solution. The distribution of the points of injection along the model are shown in figure 5. Observations of the flow were made through a pane in the tank wall. Colour slides were made of the observed flow phenomena.

3.3. Test conditions

The tests were carried out with the bare model and with the model fitted with the turbulence stimulators.

The speed ranged from 0.20 $m/_{sec}$ to 1.00 $m/_{sec}$.

The drift-angles at which the model was towed were zero, 3.0 and 6.0 degrees. The sign of the drift-angle was such that the low-pressure side of the keel was turned towards the observer.

After the first series with the rotating rods, without drift angle, had been finished, it was decided to leave off further tests with this device. The rods scored so little effect that further experiments seemed meaningless. In addition it was impossible to cover the obliquely towed model sufficiently with the narrow wake of the rotating rods.

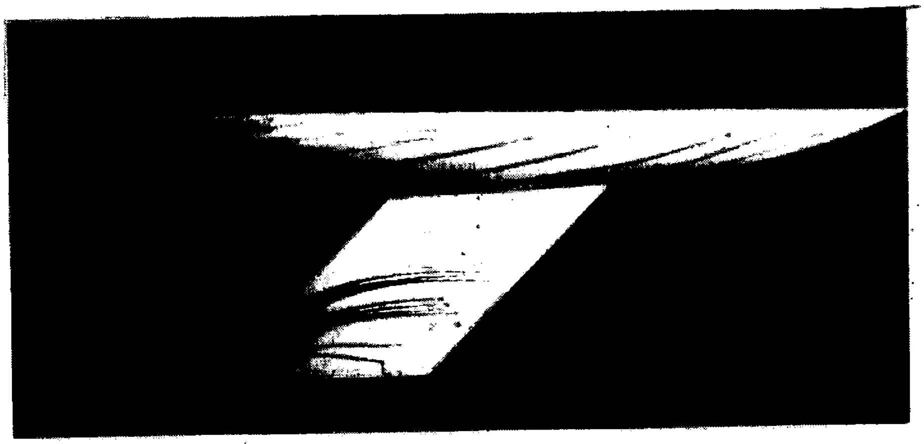
4. Discussion of the results

In all 106 slides were made. Of these 20 were selected as being representative for the series as a whole. Black-and-white photographs which are presented on the following pages were made from these slides. Unfortunately many details which were shown by the colour slides could not be reproduced satisfactorily, so the black-and-white photographs show only a part of the picture.

The following observations may serve to interprete the flow phenomena :

Laminar flow can be recognized by its long and smooth streaks, turbulent flow by the rapid diffusion of the dye. The most difficult patterns to interprete proved to be those wherein the transition from laminar to turbulent took place. It is sometimes impossible to detect where the laminar flow ends and where turbulence begins.

When separation occurred at the after part of the hull, the dye came off in clouds but the separation at the keel showed a different picture. At the keel a reverse flow very close to the keel surface existed and a sheet of nearly stagnant water was formed between the regions of reverse flow and main flow. In this sheet the dye accumulated and sank slowly, due to its slightly greater density than the surrounding water.



40

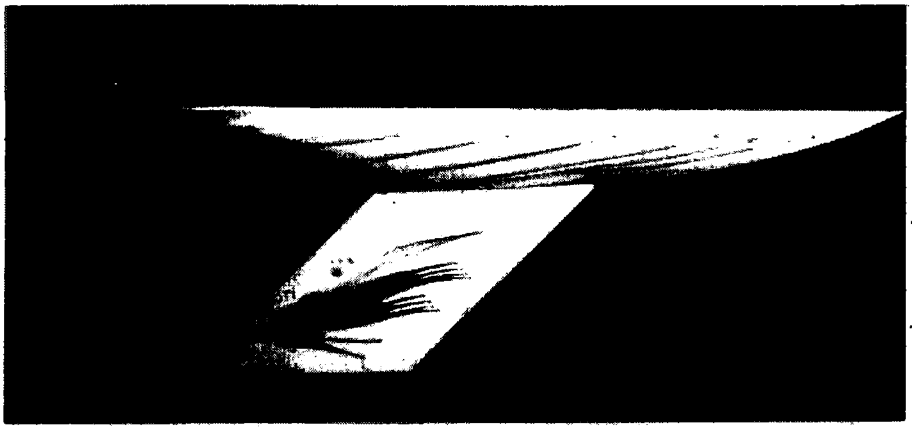
V=0.35 m/sec. β=0 degr. stim.: none

Boundary layer laminar. Flow separation at the after part of the keel. Although it is not visible here this separation also existed at the after part of the hull.

72

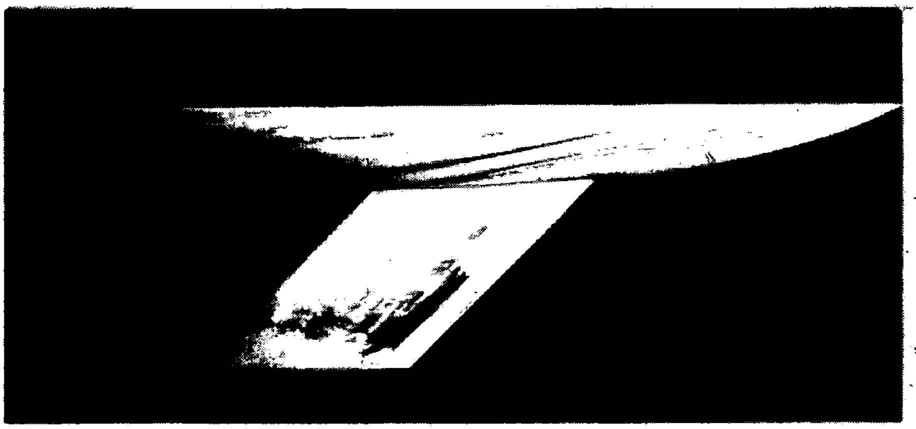
V=0.35 m/sec. β=0 degr. stim.: rot. rods

The rotating rods do not change the flow appreciably. The "high frequency" part of the produced turbulence appears to die out very rapidly.

 52

V = 0.35 m/sec. β = 3 degr. stim. : None

Flow laminar. Because of the small drift angle the separation occurs more foreward. The dye accumulates in this region, because of the reverse flow in the separation eddy.

 63

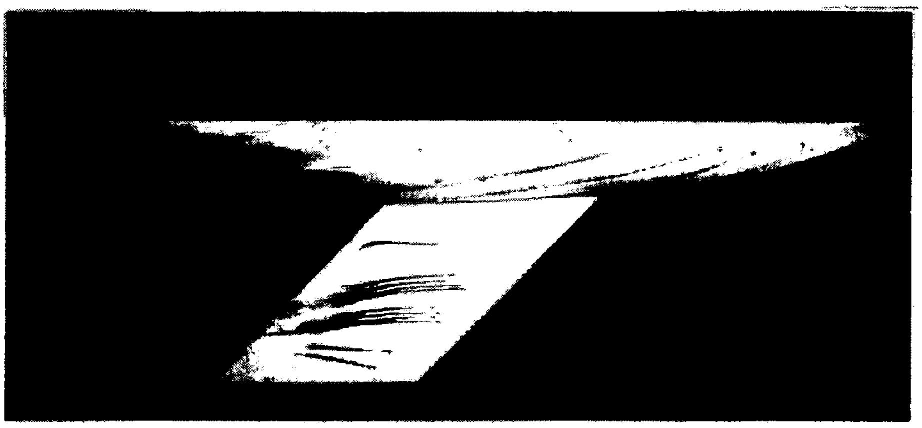
V = 0.35 m/sec. β = 6 degr. stim. : None

Flow separation behind the leading edge of the keel. The boundary layer appears to be unstable and tends to become turbulent as a result of the separation.

43

V = 0.60 m/sec. β = 0 degr. Stim. : None

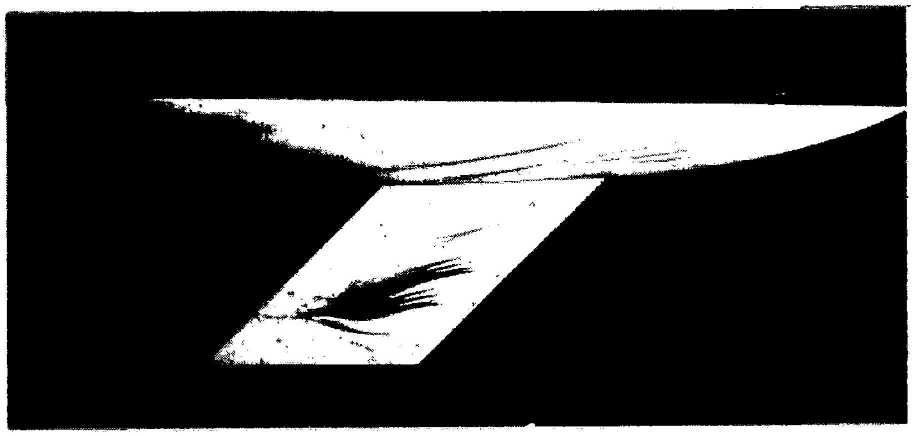
Boundary layer flow still mainly laminar. Separation at the after part of the keel.
Traces of turbulent flow at the after part of the hull.



74

V = 0.60 m/sec. β = 0 degr. Stim. : Rot. rods

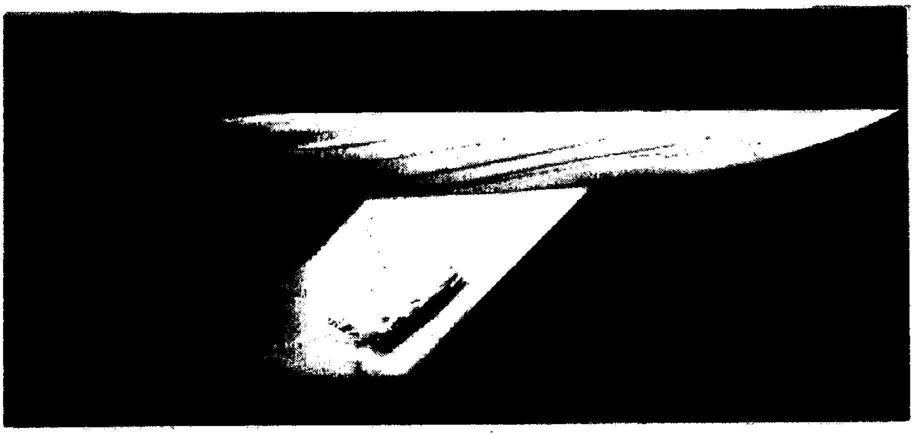
The effect of the rods is negligible.



55

V = 0.60 m/sec.   β = 3 degr.   Stim. : None

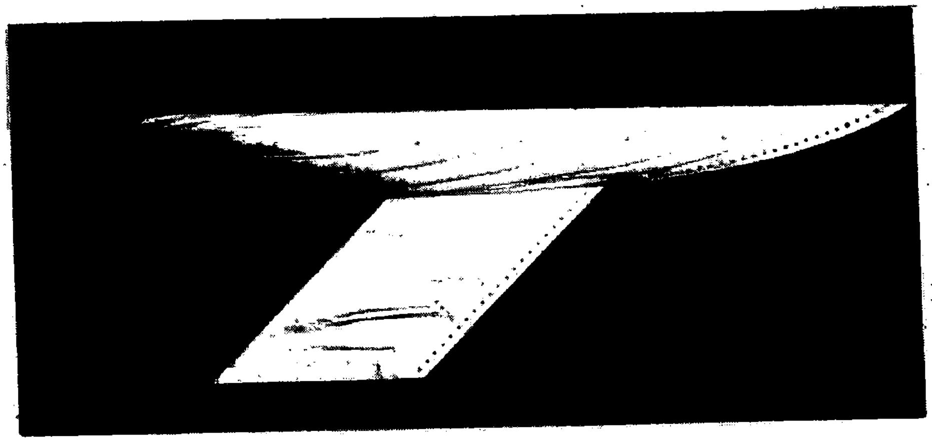
The boundary layer is still mainly laminar and the separation at the keel still existing.



66

V = 0.60 m/sec.   β = 6 degr.   Stim. : None

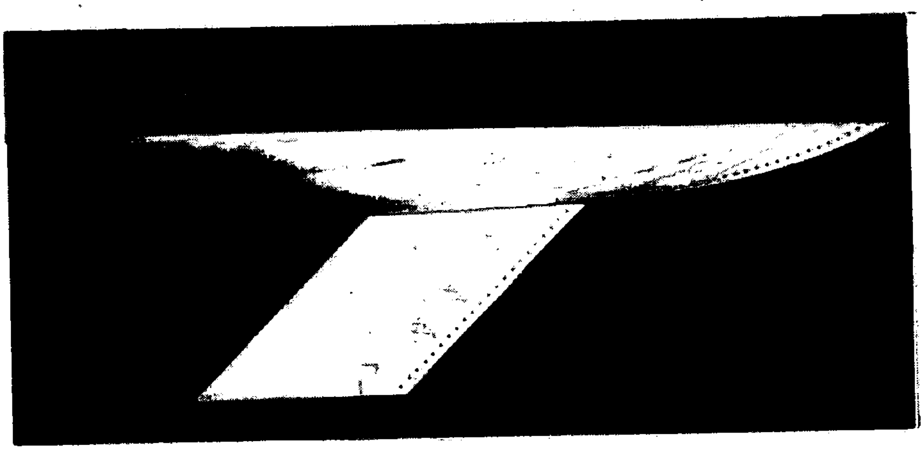
Due to the disturbance by the separation behind the leading egde of the keel the boundary layer becomes turbulent and reattaches.



6

V = 0.30 m/sec. β = 0 degr. Stim. : Studs.

At this speed the direction of flow along the body is such that the studs can not have any effect. On the keel however transition takes place. Slight separation is still present.

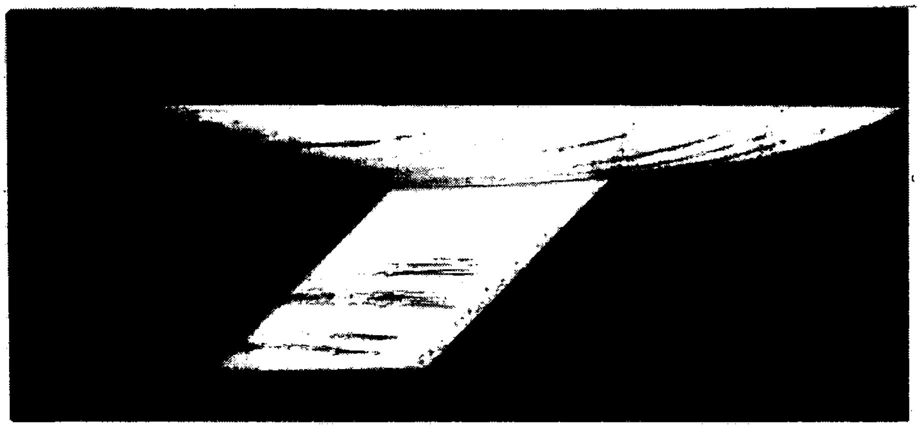


9

V = 0.60 m/sec. β = 0 degr. Stim. : Studs.

Turbulent flow. No separation.

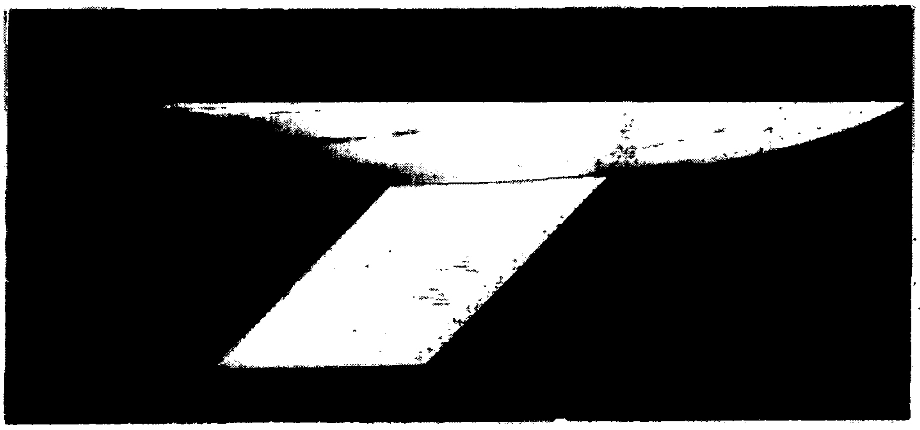
(The vertical stripes appearing at the holes are a colouration of the surface occurring during the rest-periods).



79

V = 0.39 m/sec.   β = 0 degr.   Stim. : sand

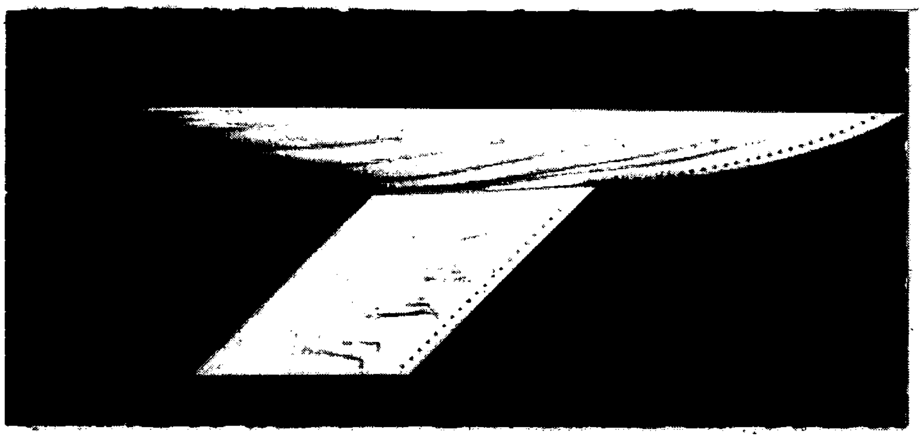
Mixed flow.   No separation



83

V = 0.60 m/sec.   β = 0 degr.   Stim. : sand

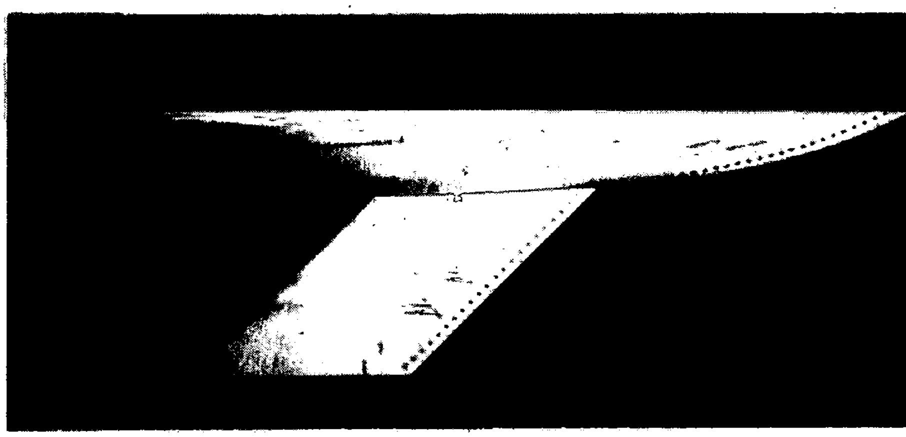
Turbulent flow.   No separation.



14

V = 0.30 m/sec. β = 3 degr. Stim. : Studs

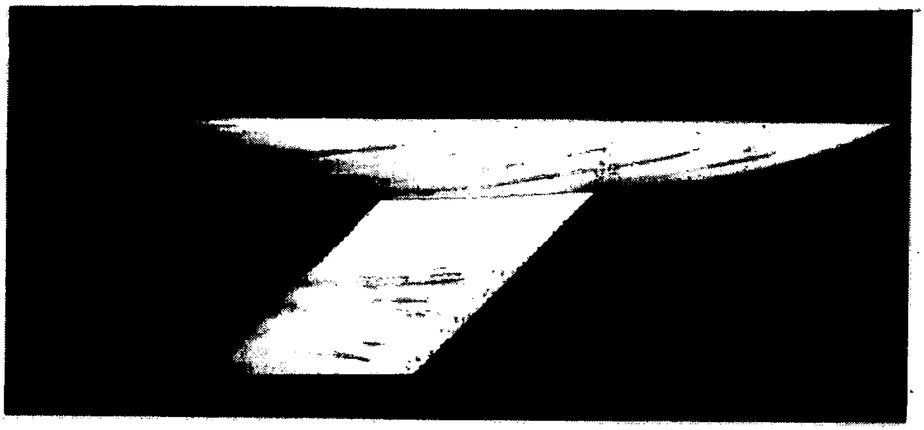
Flow laminar along the hull. Slight traces of separation appear behind the leading edge but the flow reattaches almost immediately becoming fully turbulent.



17

V = 0.60 m/sec. β = 3 degr. Stim. : Studs

Turbulent boundary layer. No separation.



90

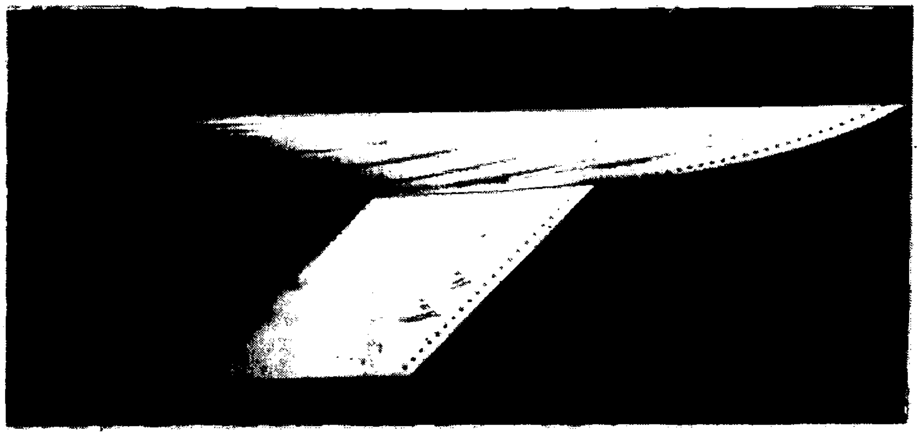
V = 0.30 m/sec. β = 3 degr. Stim. : sand

Mixed flow along the hull.
Mainly turbulent flow along the keel.
No separation.

93

V = 0.60 m/sec. β = 3 degr. Stim.: sand

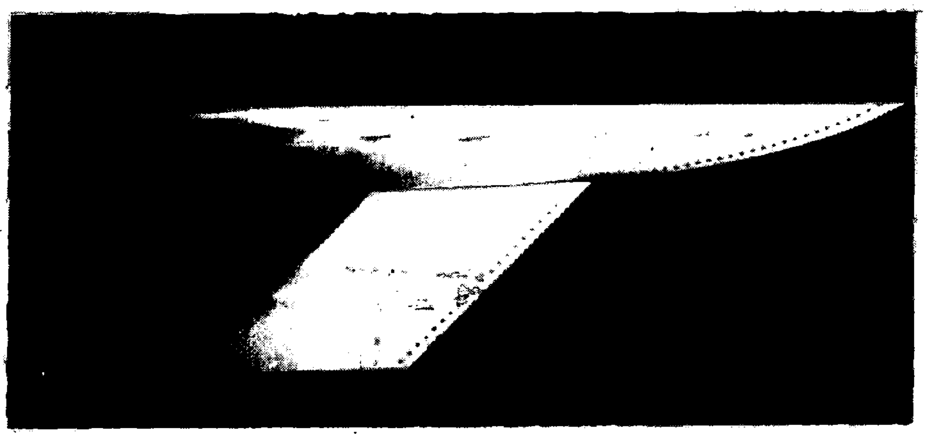
Turbulent boundary layer. No separation.



23

V = 0.30 m/sec. β = 6 degr. Stim. : Studs

Mainly laminar along the hull.
Keel mostly turbulent but showing slight separation behind the leading edge.
Turbulent reattachment.

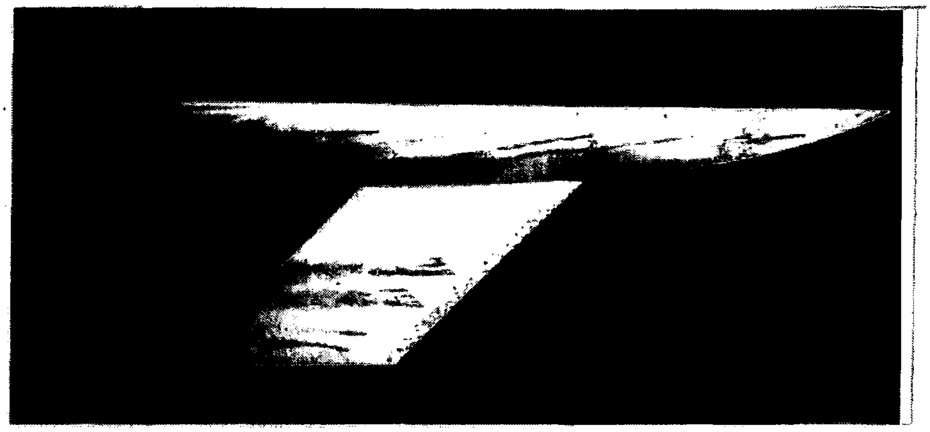


26

V = 0.60 m/sec. β = 6 degr. Stim. : Studs

Turbulent. No separation.

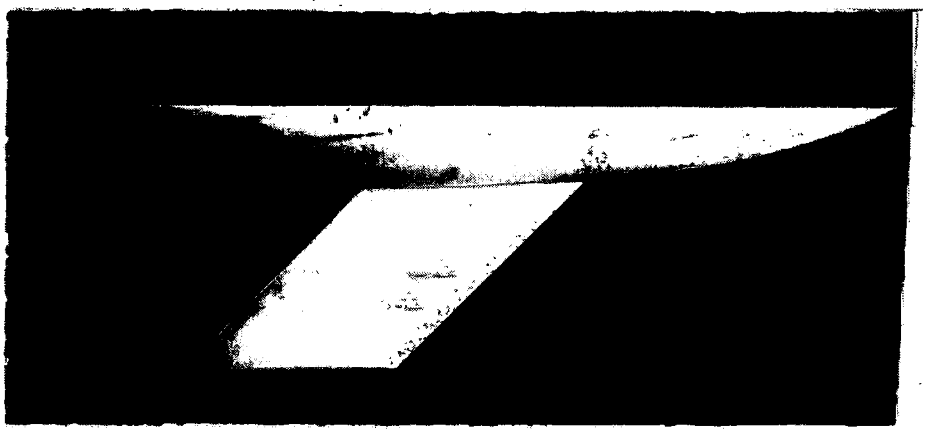
(Grey spots at the leading edge are due to the damage of the original slide).



98

V = 0.30 m/sec. β = 6 degr. Stim. : sand

Partly turbulent along the hull.
Mainly turbulent along the keel.
No separation.



102

V = 0.60 m/sec. β = 6 degr. Stim. : sand

Turbulent. No separation.

5. Conclusions

- The flow along the fore ship was directed downwards, approximately following the buttock lines. This flow direction should be taken into account when the turbulence stimulators are fitted.

- Laminar flow resulted without fail in local or more general separation.

- Although it is hard to say whether the artificially created turbulence resembles natural turbulence as regards the velocity profile in the boundary-layer and the corresponding frictional resistance, it is unmistakably effective in impeding flow separation.

- The fine turbulence which is produced by the rotating rods appears to have died out at a very short distance downstream of its source. Therefore it seems incredible that methods to increase the turbulence of the inflowing water can be very effective. At least for such small Reynolds numbers.

- The studs and the sandstrips on the keel both proved to be effective in producing turbulent flow down to very low speeds. The sandstrips proved to be slightly better in suppressing separation.

6. References.

1. Landweber, L.
"State of the Art Report on Viscons Resistance"
11 th. I.T.T.C. Oct. 1966.

2. Gatzer, H.
"On the Effect of Turbulence Stimulators on Ship Models and Shiplike Bodies"
11 th I.T.T.C. Oct. 1966.

3. Kulkarni, P.K.
"Turbulence Stimulation by Rotating Rods"
11 th I.T.T.C. Oct. 1966.

4. Prischemihin, J.N. and Poostoshny, A.F.
"Investigation of Turbulence Stimulation in the Boundary-Layer of Ship Models Tested in Towing Tanks"
Kryloff Institute. 1960.

5. Loftin, L.K.
"Effects of Specific Types of Surface Roughness on Boundary-Layer Transition"
NACL Report L - 48.

6. Doenhoff, A.E. von and Horton, E.A.
"A Low-Speed Experimental Investigation of the Effect of a Sandpaper Type of Roughness on Boundary-Layer Transition".
NACA Report 1349.

7. Schubauer, G.B. and Skramstad, H.K.
"Laminar-Boundary-Layer Oscillations and Transition on a Flat Plate
NACA Report 909.

8. Hughes, G. and Allan, J.F.
"Turbulence Stimulation on Ship Models"
Trans. S.N.A.M.E. Vol 9 1951.

9. Pringle, G.E. and Main-Smith, J.D,
"Visualisation of the Boundary-Layer Transition in Water"
Royal Aircraft Establishment,
Techn. Note no. Aero. 1688.

10. Ridgely-Nevitt, C.
"Resistance of Trawler Hull -Forms of 0.65
Prismatic Coefficient".
Trans. S.N.A.M.E. 1956.

11. Hughes, G.
"Flow Observations of a Flat Plate"
N.P.L. 1954.

12. Nordström, H.F. and Edstrand, H.
"Model Tests with Turbulence Producing Devices".
Medd. nr. 18 - 1951.
Statens Skeppsprovningsanstalt. Göteborg.

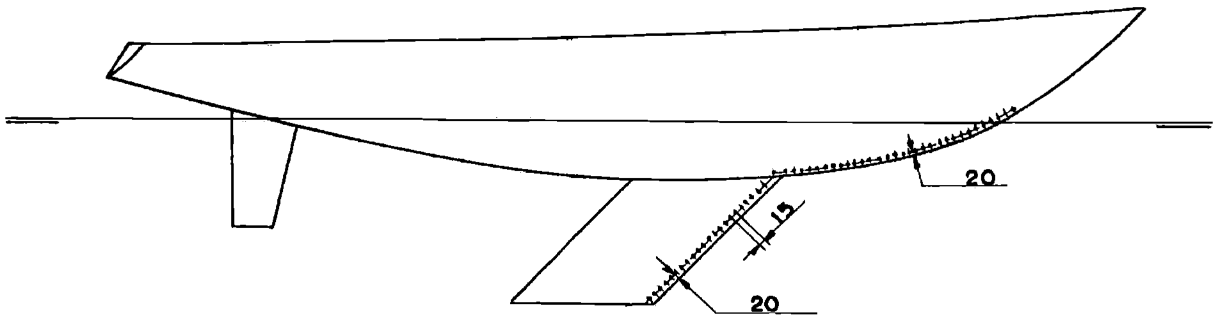


FIG. 1 POSITION OF TURBULENCENCE STUDS

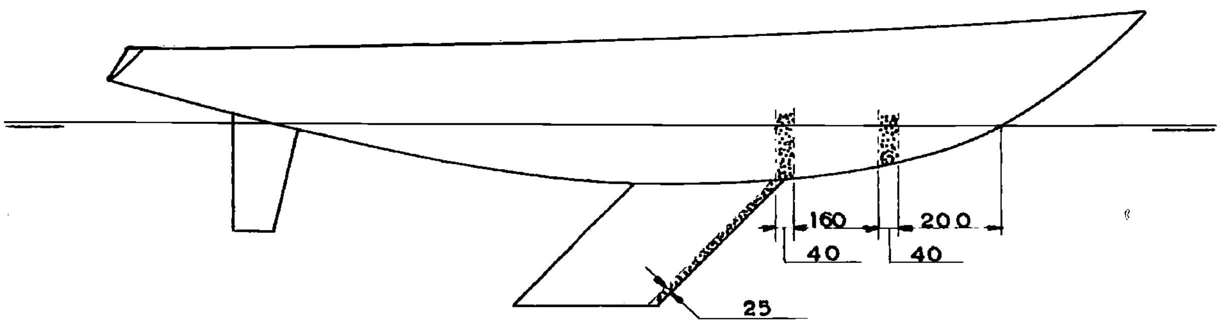


FIG. 2 POSITION OF SAND STRIPS

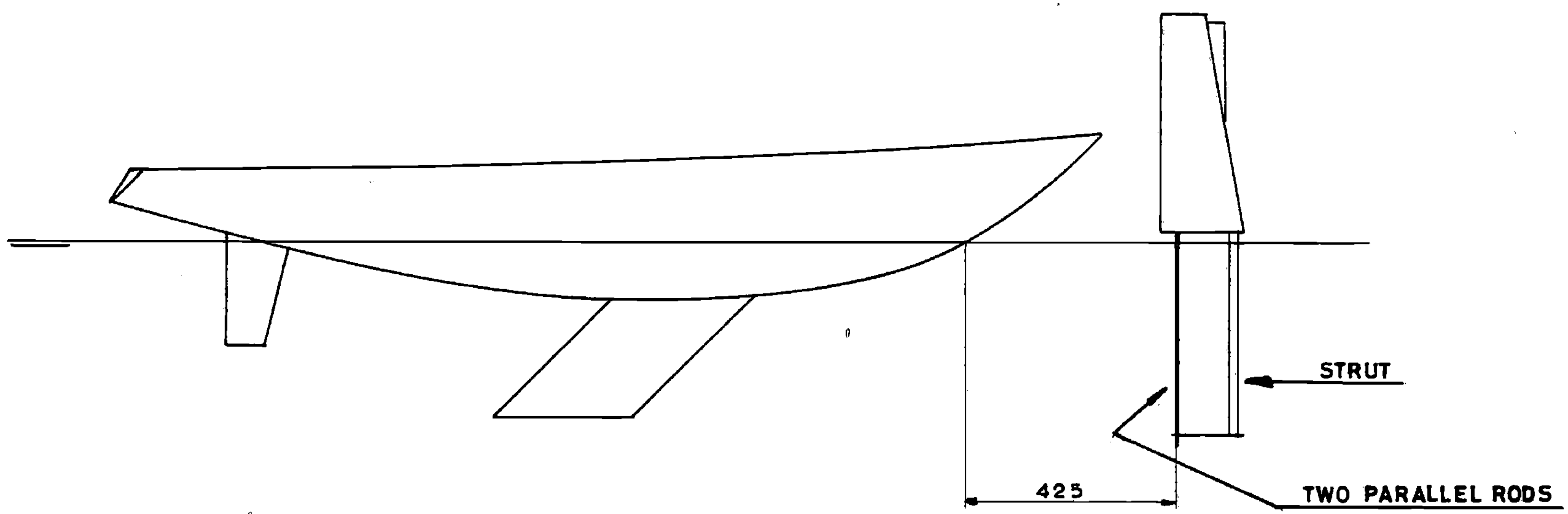


FIG. 3 POSITION OF ROTATING RODS

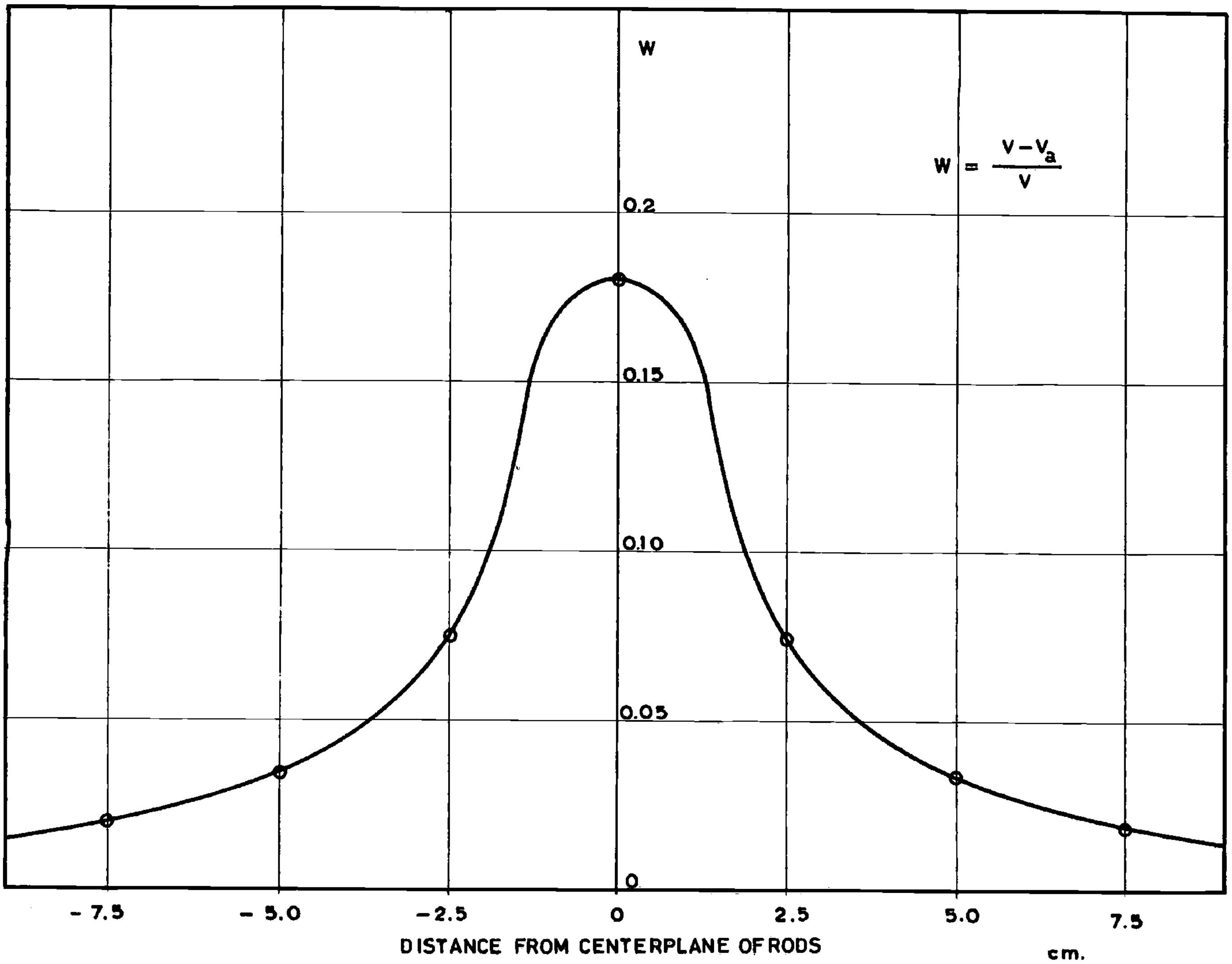


FIG 4 WAKE DISTRIBUTION BEHIND ROTATING RODS

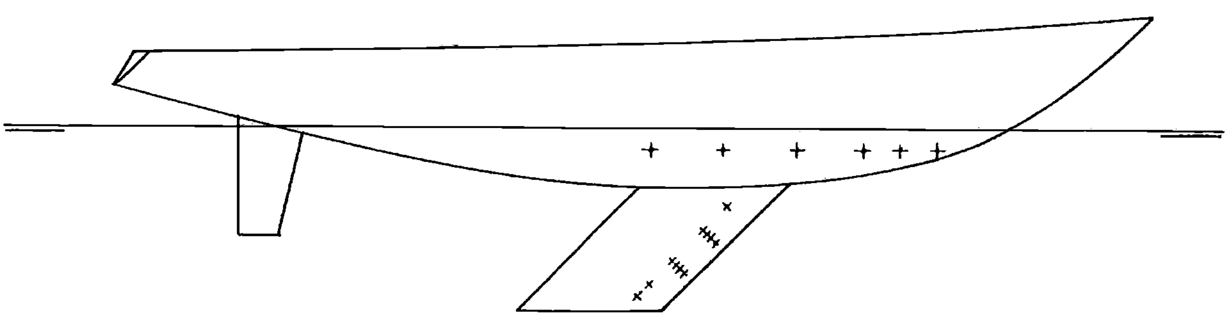


FIG 5 POINTS OF INJECTION