SUBJECT: RESISTANCE

by Dipl.-Ing. F. Mewis
(Institut für Schiffbau Rostock
Schiffbau-Versuchsanstalt Berlin/Potsdam)

Investigation of the Flow Conditions in the
Bow Wave of a Full Cargo Vessel with and
without a Bulbous Bow

General

Reductions exceeding that proportion of the total resis-
tance caused by the wave resistance have been achieved
on full cargo vessels by means of bulbous bows. In order
to be able to explain this phenomenon it is necessary to
find a new component belonging to the wave resistance but
which has been ignored in the course of previous con-
siderations. By measuring the total pressure loss in the
cross-sectional planes behind and beside the ship,
Taniguchi and Baba [1] discovered a new resistance compo-
nent caused by the eddying of the water mass at the bow
of the ship. Sharma [2] designated this component as
"wave breaking resistance".

This paper presents the results of total pressure meas-
urements in the bow wave of a full cargo vessel with
and without a bulbous bow. The aim of the investigation
is to show the influence of a bulb on the total pressure
loss in the bow wave outside of the friction boundary
layer.

Introduction

In order to prove that the area with the total pressure
loss in the bow wave of a full cargo vessel is affected
by a bulbous bow, measurements of the total pressure
were carried out in a number of cross-sectional planes in the bow wave and beside the model and the flow around the fore-body of a model of a full cargo vessel both with and without a bulbous bow was observed.

Model

The model which was investigated had the following principle dimensions:

<table>
<thead>
<tr>
<th></th>
<th>Without bulb</th>
<th>With bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L_{PP} ) [m]</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>( L_{PP}/B )</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>( B/T )</td>
<td>2.76</td>
<td></td>
</tr>
<tr>
<td>( C_M )</td>
<td>0.994</td>
<td></td>
</tr>
<tr>
<td>( C_B )</td>
<td>0.798</td>
<td>0.802</td>
</tr>
<tr>
<td>LCB [%]</td>
<td>1.61</td>
<td>+1.85</td>
</tr>
</tbody>
</table>

The frames are moderately V-shaped.

The bulbous bow selected was determined as the best of three different bulbs investigated during previous resistance tests. The bulbous bow is faired into the lines of the model with a normal bow. The frame area at the forward perpendicular is 9.5% of the area of the midship section, the length forwards of the forward perpendicular being 3% of \( L_{PP} \).

Resistance tests

In fully loaded condition as investigated in this paper, increased resistance was measured in the case of the model with a bulbous bow in the lower Froude number range \( (F_n < 0.15) \). In the case of larger Froude numbers \( (F_n > 0.15) \) it was found that the reduction in resistance grew as the speed increased. At \( F_n = 0.20 \), the reduction in the total resistance coefficient \( C_T \) is 6%. The effect of the bulbous bow is still more favourable.
the ballast condition. A considerable reduction in the resistance was found for Froude numbers of above 0.17, these reaching a maximum of 21% of the total resistance coefficient at $F_n = 0.22$.

Measurement of the total pressure

The measurements of the total pressure were taken in the flow beside the model in six cross-sectional planes in way of the forebody and in the plane of the midship section at a Froude number of $F_n = 0.20$ (speed of model $v' = 1.534$ m/s), the model being tested in fully loaded condition both with and without a bulbous bow. Fig. 1 shows the arrangement of the measurement planes. The areas of reduced total pressure shown in Fig. 2 were each obtained from about 200 measuring points.

The delayed layer was found to be thinner than was, at first, expected. Both the magnitude and the absolute value of the area of total pressure loss in the back-wave, on the surface of which numerous eddies could be discerned, immediately before the stem is smaller in the case of the model with a bulbous bow than in the model without a bulbous bow. The depth of the region with pressure loss is reduced by about one half in all of the planes investigated beside the model by the bulbous bow (Fig. 2).

In the transverse plane of the midship section, the region of the total pressure loss is forced outwards in both model versions by the boundary layers, which are of approximately equal thickness. In the case of the model without a bulb, the region of the total pressure loss was to be found in a definite form, whereas this region was reduced to a thin layer in the case of the model with a bulbous bow.
Observation of the flow in the bow wave

The reduction in resistance obtained by means of the bulbous bow could not, when comparing the wave systems generated by the model with and without a bulb, be explained by favourable interference between the wave systems generated by the bulb and the ships hull. There are, however, differences in the external appearance of the bow wave. The eddying part of the back-wave is reduced by the bulbous bow.

The thickness of the eddying layer in the back-wave was measured by means of a thread probe and optical observations were carried out in the back-wave in the direction of flow. The most important result of these observations is the fact that the externally visible area of eddies in the back-wave is only a turbulently eddying layer on the exposed surface and that the thickness of this layer decreases rapidly as it flows to the rear. Both the horizontal extent and the thickness of this layer are reduced by the bulbous bow. The thickness of the layer in which the presence of eddies was proved by the thread probes is less than the depth of the region of total pressure loss obtained from the pressure measurements.

Summary of the results

The results presented here show that the flow conditions in the back-wave of a full ship are influenced by a bulbous bow. It could be proved that a region of total pressure loss resulting from the back-wave is present in the bow wave and in the midship section plane and that the size of this region can be reduced by means of a bulbous bow.
References


**Fig. 1**
Arrangement of the measurement planes on the model

**Fig. 2**
Lines of constant total pressure relativ to the total pressure of the undisturbed flow

without bulbous bow

\[
\frac{P_{\text{total}}}{P_{\text{total,0}}} = \begin{cases} 
0.70, 0.80, 0.85, 0.90, 0.99 \\
0.70, 0.80, 0.85, 0.90, 0.95 \\
0.70, 0.80, 0.85, 0.90, 0.95 \\
0.70, 0.80, 0.85, 0.90, 0.95 \\
0.70, 0.80, 0.85, 0.90, 0.95 \\
\end{cases}
\]

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with bulbous bow

\[
\frac{P_{\text{total}}}{P_{\text{total,0}}} = \begin{cases} 
0.85, 0.90, 0.95, 0.99 \\
0.85, 0.90, 0.95, 0.99 \\
0.85, 0.90, 0.95, 0.99 \\
0.85, 0.90, 0.95, 0.99 \\
0.85, 0.90, 0.95, 0.99 \\
\end{cases}
\]
without bulbous bow

with bulbous bow

section plane 19

section plane 18

section plane 10