ABSTRACT: In order to achieve a good understanding of how the interceptor works, a research project has been started using a CFD RANS-multiphase code and Towing Tank experimental. In this work is presented the progress made on the research obtained from subsequent Towing Tank experiments. The study has been focused on the variations of interceptor’s effectiveness induced by deadrise angle, longitudinal centre of gravity LCG and interceptor’s geometry. In particular have been tested, at $R_n > 5.8 \times 10^6$, three V-shaped bottom prismatic hulls, 2.8 m long. The models have deadrise angles $\beta = 10$, 20 and 30 deg respectively and the $F_nV$ range studied is $1.3 \pm 2.8$. These evaluations have been performed for different interceptor’s height and with two values of LCG. Finally, in order to separate the influence of interceptors on lift variations and trim reductions, test with fixed trim and imposed sinkage on different device heights have been performed.

1 INSTRUCTIONS

In this work are presented the developments of previous test sections whose results have been showed in (De Luca et alii 2010). The past tests highlighted the effectiveness of interceptors as high lift device. The results of the new tests have strengthened this quality and showed the relation of the interceptor’s performances with deadrise angle $\beta$.

Moreover, in the next pages it will be showed the first results of tests on interceptor fixed not in contact with the hull bottom or placed at a forward position.

2 EXPERIMENTAL PROGRAM & RESULTS

2.1 Tested Model

The next figures show the prismatic model tested. Table 1 synthesizes hull form by the main parameters.

<table>
<thead>
<tr>
<th>$\beta$ (deg)</th>
<th>10</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{WL}$ (m)</td>
<td>2.375</td>
<td>2.387</td>
<td>2.385</td>
</tr>
<tr>
<td>$B_{WL}$ (m)</td>
<td>0.600</td>
<td>0.600</td>
<td>0.600</td>
</tr>
<tr>
<td>$L/B$</td>
<td>3.958</td>
<td>3.978</td>
<td>3.975</td>
</tr>
<tr>
<td>$\Delta$ (kg)</td>
<td>102.8</td>
<td>102.8</td>
<td>102.8</td>
</tr>
<tr>
<td>$L_{CG}/L_{WL}$</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>$\tau_s$ (deg)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>$A_T/A_X$</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 1. Main parameters of tested models
2.2 Experimental program.

A wide analysis of dimensions of typical interceptors have been tested on the three models shown before.

Moreover a new branch of this research has been started. In particular have been performed tests on two unconventional arrangements of interceptors:
- split from the bottom and
- in couples interceptors.

The conventional interceptors have been tested for different dimensions of devices and positions of centre of gravity.

<table>
<thead>
<tr>
<th>i/LWL</th>
<th>10 deg</th>
<th>20 deg</th>
<th>30 deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.19×10^{-4}</td>
<td>10 deg</td>
<td>10 deg</td>
<td>10 deg</td>
</tr>
<tr>
<td>8.38×10^{-4}</td>
<td>10 deg</td>
<td>10 deg</td>
<td>10 deg</td>
</tr>
<tr>
<td>1.26×10^{-3}</td>
<td>10 deg</td>
<td>10 deg</td>
<td>10 deg</td>
</tr>
<tr>
<td>1.68×10^{-3}</td>
<td>10 deg</td>
<td>10 deg</td>
<td>10 deg</td>
</tr>
<tr>
<td>2.09×10^{-3}</td>
<td>10 deg</td>
<td>10 deg</td>
<td>10 deg</td>
</tr>
</tbody>
</table>

Table 2. Conventional interceptors: test conditions

The tests on split interceptors have been performed on β 20 deg model. It has been arranged with i/LWL=1.68×10^{-3}. The device has been fixed at a distance from the bottom, h, of 0.25×i. Next figure shows the arrangement.

The same model has been tested with a second forward device. In particular The model has been arranged with two interceptors, parallel to the transom, whose i/LWL is 1.26×10^{-3}. The forward one has been placed at 52.4% of L_WL from the stern.

Next figures show the performances of bare hulls having two values of L_CG/L_WL: 0.332 and L_CG/L_WL: 0.368 (i.e. κ_3 = 2.0 and 3.0 deg respectively). The models have been tested down by the stern to avoid wetted bows and non prismatic geometry. These values have been taken into account to evaluate the effectiveness of the models arranged with interceptors.

2.3 Conventional interceptors

Next paragraphs describe the results obtained carrying out the program shown in table 2. The results are reported as fraction of resistance of corresponding bare hull.

The dynamic trims are evaluated from zero heel condition (L_CG/L_WL = 0.44 ⇒ κ_3 = 0)

The range of speed considered is Fn_v = 1.3 ÷ 2.8.
**β 10 deg Model**

![Figure 5](image1)

Figure 5. Effectiveness at different $i$

![Figure 6](image2)

Figure 6. Dynamic trim at different $i$

![Figure 7](image3)

Figure 7. Effectiveness at different $i$

**β 20 deg Model**

![Figure 9](image4)

Figure 9. Effectiveness at different $i$

![Figure 10](image5)

Figure 10. Dynamic trim at different $i$

![Figure 11](image6)

Figure 11. Effectiveness at different $i$

![Figure 8](image7)

Figure 8. Dynamic trim at different $i$

![Figure 12](image8)

Figure 12. Dynamic trim at different $i$
The previous figures highlight that:

- the best performances are in a range of speed $F_n V = 2.0\div 2.2$;
- the resistance reductions are inversely proportional to the deadrise angle; this is probably related to a greater transversal flow at a greater $\beta$ that is associated to a lower effectiveness of the bottom in pressure keeping;
- the performances, of all the models, at highest speeds, underline extreme trim corrections; coherently, the interceptor's dimensions have to be smaller for higher speeds.

2.4 Effectiveness of Interceptor as High Lift Device

In previous works (De Luca et Alii 2010) it has been sown that the interceptor effectiveness is strongly associated to a lift growth, in addition to trim reduction.

To estimate the influence of $\beta$ on this quality the three models have been tested at $F_n V = 1.96$ maintaining constant value of dynamic trim. In particular for each models it has been chosen the trim related to the best interceptor performance ($\tau = 3.75, 3.49, 3.41$ deg respectively for $\beta = 10, 20, 30$ deg). Because of the similar values of $\tau$ a direct comparison is significant:

In diagram the rising of centre of gravity of the model are shown and resistances are expressed as fraction of bare hull performances.

The figure confirms the strong effectiveness of interceptor as high lift device and the dependence of its performances on deadrise angle.

2.5 Unconventional Interceptors

A research on unconventional interceptors is in progress contemporary with the program shown before. In particular two studies are in an initial stage:

- interceptors fixed at a small distance from the bottom (split from the bottom)
- in couples interceptors.

2.5.1 Interceptor split from the bottom

As known the interceptors determine a closed vortex in the corner connecting device and hull. To remove or to reduce the vortex the $\beta 20$ model has been arranged with the split interceptor showed in figure 2.

This kind of device determines:

- faster water on the interceptor;
- an outgoing shift of the device from sub-laminar layer;
- a flow between hull bottom and interceptor.

It is not easy to evaluate how much are influential the first two items. The third one implies an appreciable variation of velocity field.

Trial tests are carried out on $\beta = 20$ applying a device dimension of $i/L_{WL} = 1.68\times10^{-3}$ located at a
distance $h = 0.25i$ from the bottom. The model has been tested with $L_{CG}/L_{WL} = 0.332$.

### 2.5.2 In couples Interceptors

According to the interceptor as high lift device, to magnify the lift, two interceptors have been placed under the bottom of the same $20$ deg model with $L_{CG}/L_{WL} = 0.332$. The first one is a typical stern interceptor having $i/L_{WL} = 1.26 \times 10^{-3}$; the second one has been located at $0.524 L_{WL}$ from the stern. The forward interceptor has the same extension of the astern one. Both the devices are placed in transversal planes.

The effectiveness of in couples interceptors results extremely good at highest speeds. It reaches more than $25\%$ of resistance reduction at $F_{nV} = 2.5$ and $20\%$ at $F_{nV} = 2.8$.

It is important to note that both devices shown great promise despite dimensions and positions have not been optimized.

![Figure 16. Twin interceptors arrangement](image)

**Figure 16. Twin interceptors arrangement**

### 2.5.3 Results

Next figures show the performances of non conventional interceptors expressed in terms of resistance ratio and dynamic trim. The split device curve, performs the envelop of the best performances for $F_{nV} < 2.3$ ($i/L_{WL} = 2.09 \times 10^{-3}$ for $F_{nV} < 2.0$ and $i/L_{WL} = 1.26 \times 10^{-3}$ for $2.0 < F_{nV} < 2.3$).

For higher speed, although it is not the lower, it maintains good performances.

![Figure 17. Comparison between effectiveness of conventional and unconventional interceptors](image)

**Figure 17. Comparison between effectiveness of conventional and unconventional interceptors**

To avoid the wetted bow effects that make the performances worse at high speed (and very low trim), all the models have been tested down by the stern. As a consequence, the results expressed as resistance fraction of bare hull data, are effected by the not excellent resistance due to the small $L_{CG}/L_{WL}$ of the bare hull.

In order to avoid overestimating the virtues of the arrangements tested, the next figures are proposed. In figure 19 are shown the best static trim angles (for the lower resistance) and the corresponding resistances in all the speed range.

![Figure 19. Bare hull: best performances and corresponding static trim](image)

**Figure 19. Bare hull: best performances and corresponding static trim**

### 2.6 A stricter effectiveness analysis

To avoid the wetted bow effects that make the performances worse at high speed (and very low trim), all the models have been tested down by the stern. As a consequence, the results expressed as resistance fraction of bare hull data, are effected by the not excellent resistance due to the small $L_{CG}/L_{WL}$ of the bare hull.

In order to avoid overestimating the virtues of the arrangements tested, the next figures are proposed. In figure 19 are shown the best static trim angles (for the lower resistance) and the corresponding resistances in all the speed range.
The figure 20 shows the resistances of the model as fraction of the resistance of the same model sailing with the best position of CG for every single speed.

The figures 21 and 22 show the comparison between the bare hull (at the best positions of CG for each speed) and the different interceptors arrangements.

It is important to clarify that in the figures 21 and 22, \( R_{T_i} \) are related to \( R_{T_{\text{best-trim}}} \) that is not resistance of a real hull but is the performance of the ideal hull that adapts the CG to the speed. Obviously, this way to evaluate the effectiveness is strongly precautionary.

3 CONCLUSIONS & FUTURE WORK

The experimental data obtained highlight same aspects of the interceptors’ physical model that seem useful to optimize the employment of these devices.

Among these, unconventional interceptors seem to have a future in high speed applications. Reassumming the considerations above expounded we have observed that:

1. the effectiveness of interceptors highlighted in previous work for \( \beta \) 20 deg model has been confirmed in a wide range of \( \beta \) (10 ÷ 30 deg).
2. deadrise angle has a strong influence on interceptors' effectiveness; great \( \beta \) implies significant reductions of high lift effect and, consequently, increasing of resistance;
3. the range of \( F_{NV} \) of best performances of the devices are quite not dependent on \( \beta \) values (1.9<\( F_{NV} \)<2.3);
4. the split interceptor has shown a good effectiveness in a wider range of speed: it seems to be a competitive alternative (in terms of resistance) to the \( i \)-variable interceptors;
5. in couples interceptors have generate the best overall performances; comparing the results with a bare hull at same CG, they reach more than 25% of resistance reductions;
6. the effectiveness of the interceptors is not only confirmed as trim controller (i.e. useful to correct wrong CG positions) but is quite effective also comparing it to bare hull performances at best CG position.

Finally, it seem very probable that different arrangements of unconventional devices should be even better. In particular it will be tested different \( i/h \) ratios, for split interceptors, and different positions and dimensions for in couples devices.

4 NOMENCLATURE

\( \tau \) Dynamic Trim
\( \tau_s \) Static Trim
\( \beta \) Deadrise angle
\( h \) Interceptor distance from the hull bottom
\( i \) Height of the stern interceptor
\( y \) Height of the forward interceptor
\( L_{CG} \) Distance of Centre of Gravity from the transom

CG Centre of gravity
5 REFERENCES


Savitsky D., Morabito M. (2010): “Surface Wave Contours Associated with the Forebody Wake of Stepped planning hulls” SNAME, Marine technology; Vol 47 no 1, January, pp. 1-16

