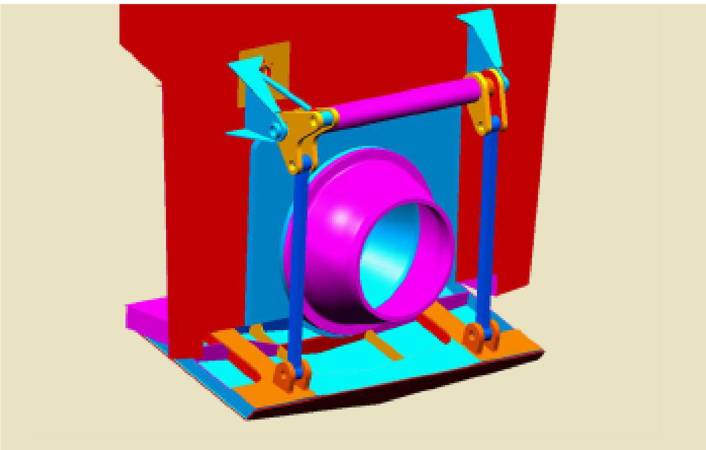
INTERCEPTORS/TRIM TABS/FORCE PRODUCERS FOR SHIP MOTION CONTROL

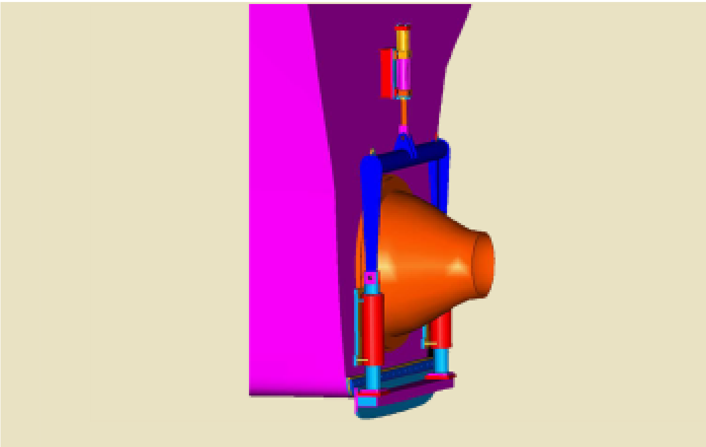
DETAILS

Trim tabs have been used to optimize the running trim of displacement, semi-planning, and planning vessels for many years. In 1991, Maritime Dynamics, Inc. (MDI) pioneered the use of these devices as force producers to actively control the motions of monohulls and catamarans. Well over 100 MDI ride control systems incorporating trim tabs have been commissioned on fast ferries.



Trim Tab

Interceptors have been successfully used on airplane wings, missiles, and boats to create lift forces for attitude control. Within the past several years, interceptors have been successfully used as force producers on fast ferries to actively control motions. Approximately twenty fast ferries have been fitted with ride control systems incorporating interceptors.



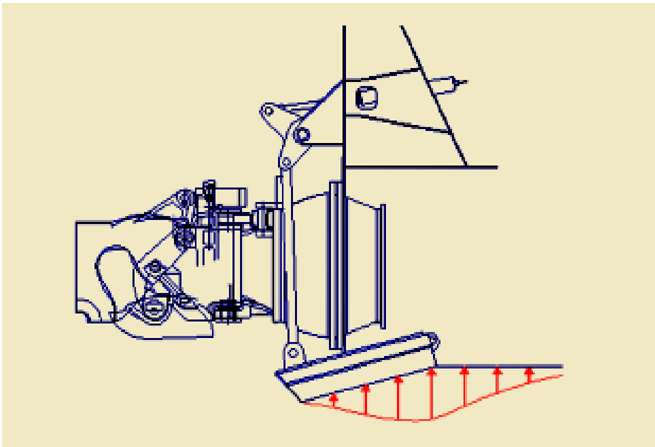
Interceptor

The primary advantage of trim tabs is that they can produce larger forces for ride control than interceptors. However trim tabs are more difficult to integrate, add weight to the vessel, and require significant power for operation. Interceptors can be easily integrated with most transom configurations, are light, and require less power for operation.

MDI conducted a series of model tests to compare and characterize the performance of trim tabs and interceptors. Model tests were necessary because there is no full-scale data which compares trim tab and interceptor performance on the same hull. The tests were conducted by towing a 7-meter monohull model fixed in six degrees-of-freedom and measuring the pressure distribution, lift force, hull drag, and pitch moment generated by deployment of the two control surfaces.

Both control surfaces had identical span as this dimension largely determines the amount of lift generated by each device. In most ride control installations incorporating trim tabs, or interceptors, the span has to be maximized within the constraints imposed by the transom arrangement to obtain sufficient lift force to damp the motions under heavy weather operating conditions.

Bottom pressures measured near the trim tabs and interceptors were distinctly different. Pressures generated by tabs peak just aft of the hinge and are distributed over the tab and hull plating ahead of the tab as shown below:



Trim Tab Pressure Distribution

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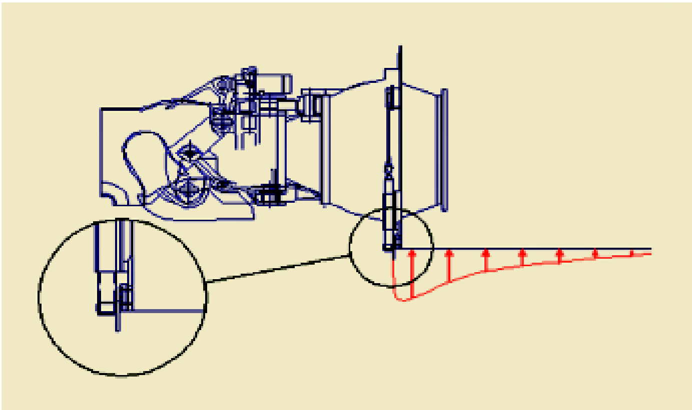
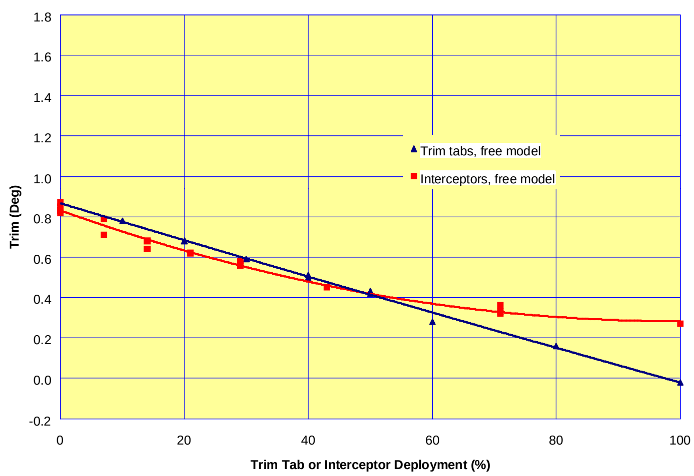
Bottom pressures generated by interceptors peak at the interceptor and are distributed on the hull plating ahead of the interceptor as shown below:



Interceptor Pressure Distribution

The following graph illustrates the effect of trim tab and interceptor deployment on trim angle from free-to-trim tests of the same model. The reduction in trim with tab and interceptor deployment are nearly identical up to 55% deployment.

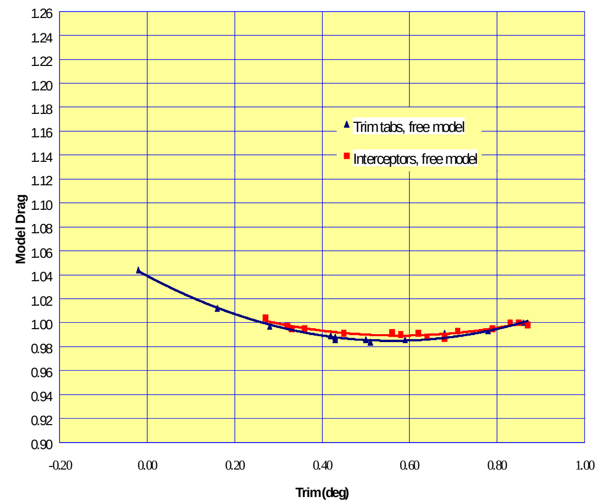


Trim Comparison

At larger deployments, the trim tabs continue to reduce the trim angle in a linear fashion while the interceptors loose their effectiveness. The tabs provided approximately 66% more lift at maximum deployment.

The next graph shows the relationship between total model drag and trim angle as the tabs or interceptors are deployed. Total drag is assigned a value of 1.0 at the initial trim angle of 0.85 deg, with the tabs and interceptors set flush with the hull plating (i.e., 0% deployment). As the tabs or interceptors are deployed, the bow down pitch moment reduces the trim angle. The minimum total drag, with a value of 0.985, occurs at a trim angle between 0.6 deg and 0.5 deg, using about 40% deflection of either device.

The curves for the two devices are essentially identical down to just below 0.3 deg trim, at which point the interceptors were 100% deployed, and the tabs were at 60%. Further deployment of the tabs reduced trim angle to less than 0 deg.



Drag Comparison

These free-model results are consistent with fixed-model measurements of incremental lift and drag from the two devices. These show that the lift-to-drag ratio of the devices is essentially the same, though the tabs are capable of producing larger forces at maximum deployment. It should be remembered that the span (width) of the two devices were the same on the model. Depending on the aft hull lines, it may be possible to use a larger span for interceptors, and at least partially offset their lower force capability. On the other hand, tabs can be arranged to extend beyond the transom, thereby increasing their area, and increasing the total waterline length of the hull. At the Froude number of a typical fast ferry in cruise conditions, this has a favorable effect on reducing the drag of the hull.

Another aspect of the trade-off between tabs and interceptors is their potential interaction with the waterjet thrust vectoring and reversing that provides the excellent maneuverability of many ferry designs in harbor. To get the maximum control forces available from waterjets, it is essential that the hull shape and ride control effectors do not interfere with the reverse thrust efflux at any steering angle. By using tabs that are hinged forward of the transom, they can be retracted into a hull recess, thereby allowing the operator to take full advantage of all the control power available from the waterjets.

In addition to the quasi-static lift forces discussed above, trim tabs are known to produce dynamic forces

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because the tab has mass, and there is an added mass of water that is displaced by dynamic operation of the trim tab. These mass terms produce dynamic lift forces due to acceleration of the tab and associated water during active ride control. Measurements of actuator cylinder pressures during full scale trials with tabs suggest that this dynamic force can be momentarily as large as the static force during periods of large tab motions.

Dynamic forces generated by tabs are proportional to tab span and the square of tab chord. Therefore the larger the tab, the greater is its dynamic force capability. Another benefit of this dynamic force capability is that it does not decrease with speed squared as does the steady state force (i.e., tabs continue to produce dynamic forces at lower speeds). Tabs can readily be shown to produce significant roll moments at zero speed (dockside).

Interceptors are lighter, and have essentially zero added mass dockside. There may be an added mass term at speed, but this is likely to be much lower than with tabs. Interceptors, therefore, not only have a lower static force capability, but this static force will be augmented by dynamic terms to a lesser extent than is found with tabs.

This comparison suggests that the hull resistance will be the same at optimum trim, regardless of whether the vessel is fitted with tabs or interceptors. However, if maximizing the performance of a ride control system is the objective, then trim tabs can generate significantly larger roll and pitch moments than interceptors. Interceptors are a viable alternative to tabs in special circumstances such as:

a) When absolute maximum lift force is not necessary

b) When trim tab area is constrained by the transom arrangement

c) When weight is critical, and/or the LCG cannot move further aft

d) When the hull shape is such that the reverse flow from the waterjets does not impinge on the transom

While not having the maximum lift of tabs for ride control, interceptors have advantages in reduced fabrication, operation and maintenance costs due to their simplicity of design and reduced hydraulic power requirements.

The following table compares trim tabs to interceptors as force producers for ship motion control. MDI recommends that the naval architect, builder or operator contact us for a trade-off of these parameters and the vessel's ride quality before deciding which device to fit.

Parameter	Trim Tabs	Interceptors
Maximum Lift Developed for Ride Control	Significantly Higher	Lower
Hull Resistance at Optimum Trim	Same	Same
Weight	Higher	Lower
Installation	Harder	Lower
Cost	Higher	Lower
Maintenance	Harder	Simpler
Damage from Floating Objects	Minimal Risk	Higher Risk
Established User Base	Large	Smaller

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