# How Differently Shaped Hulls Perform When They Encounter Standing Waves At Rest


Giulio Basilico

Advisors: Mr. Futterman and Dr. Langauni

Science Department, Poly Prep CDS, Brooklyn 11228


## 1. Introduction:

There are essentially three types of hulls for marine craft: displacement hulls, planing hulls, and semi-planing hulls (Svahn, 2009). Though worthy of study, this research focuses on planing hulls, specifically, a subset known as motorized planing hulls.

Recently, there has been increased attention and interest in high-speed marine vehicles (HSMVs) for both military and commercial applications (Collu et al., 2010). Combined with t the development of lighter and more reliable hulls and propulsion systems, it has forced designers to pay more attention to hulls than they have previously. Outboard engines now have very low weight-to-power ratios and are very reliable (De Marco et al., 2017). These features make them suitable from military to racing applications. New composite materials have also reduced the weight of hulls compared to those made from traditional hand-made layups, sometimes by up to 30%. Growth in the use of high-speed planing craft across many sectors (De Marco et al., 2017) have led to multiple designs for these crafts, including but not limited to: hard-chine planing hulls, stepped planing hulls, catamaran hulls, and hydrofoils (Svahn, 2009; Baker, 1968; Sherman and Fisher, 1975).

This study was designed to evaluate the differences in performance between two planing hulls when they encounter standing waves at rest. While they share the same overall dimensions, one is a more traditional hard-chine planing hull while the other is a more modern stepped planing hull. Stepped hulls seem to keep a more consistent laminar flow of water over themselves compared to traditional hard-chine hulls, which allows them to avoid "porpoising." That describes the tendency of some planing boats to start pitching up and down at higher speeds, even on flat water, which makes for a ride that is uncomfortable and difficult to control.

## 2. Methodology:

To make the standing waves in the fish tank, a custom 3D-printed paddle (**1**) was connected to a piston (**2**), which was controlled by a frequency generator (**3**). The piston and frequency generator were held in place with an overbuilt brace made from ¾ inch pressure-treated plywood and 2x4 dimensional lumber (**4**). An accelerometer (**5**) taped to the hulls (**6**) fed data into an Arduino mini-computer, whose outputs were recorded into an Excel spreadsheet using a program called PuTTY. Raw data was graphed in Excel with transient behavior at the beginning and end of each experiment removed.

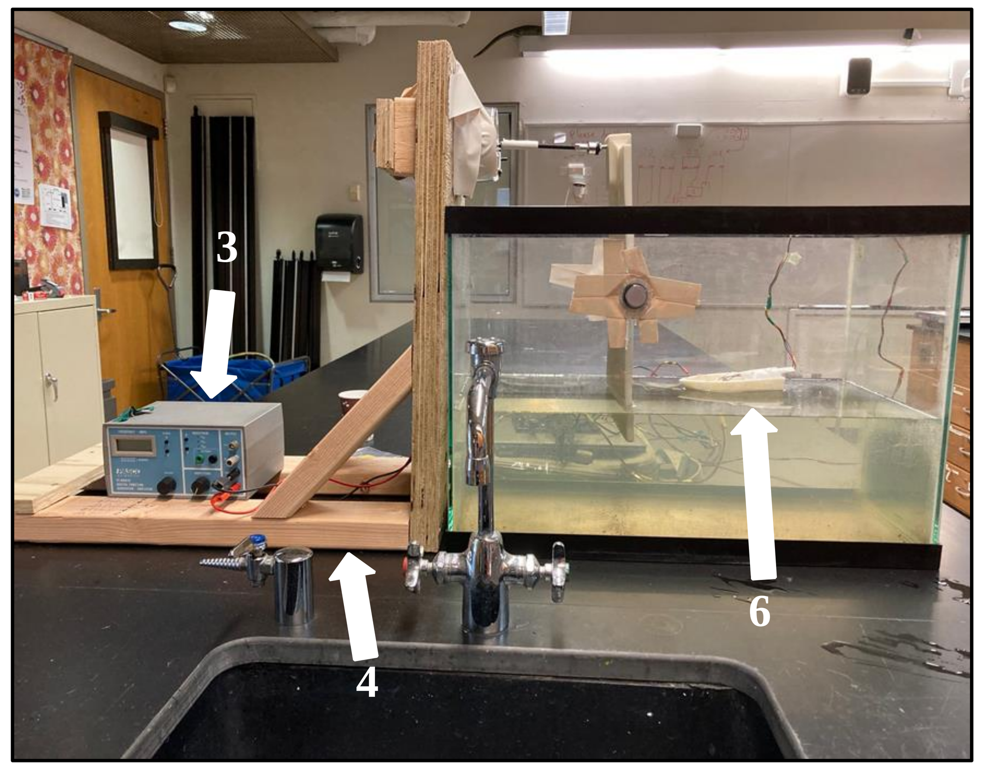


Fig. 1: Complete wave generator system.

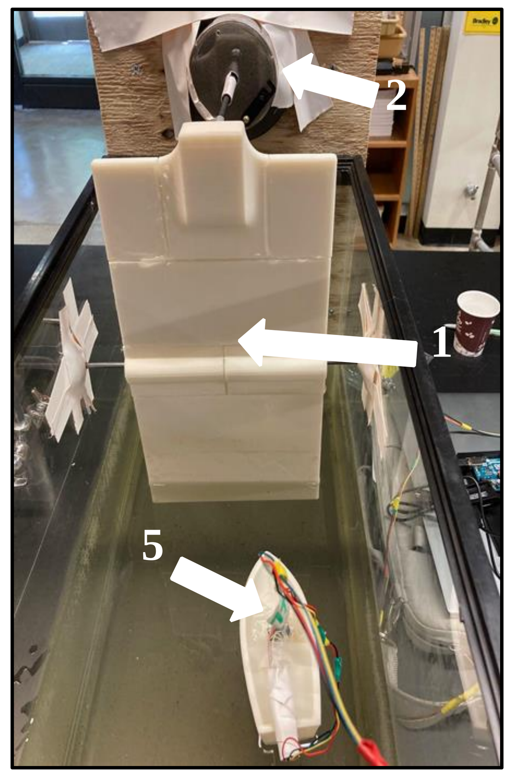


Fig. 2: Close-up of wave generator system.

## RESEARCH QUESTION:

## How does the performance of similarly sized, but differently shaped hulls compare when they encounter standing waves?

## 3. Results:

6 Trials for each hull were conducted (3 at half amplitude and 3 at full amplitude of the frequency generator).

- The odd-numbered trials were done at half amplitude and the even-numbered ones were done at full amplitude.
- Trials 1 and 2 were done at 2.70 Hz, trials 3 and 4 were done at 3.27 Hz, and trials 5 and 6 were done at 3.61 Hz.
- Those frequencies were chosen because they are the 2nd, 3rd, and 4th harmonic frequencies, respectively. The 1st harmonic was not easily determined in the tank and hence was not included.

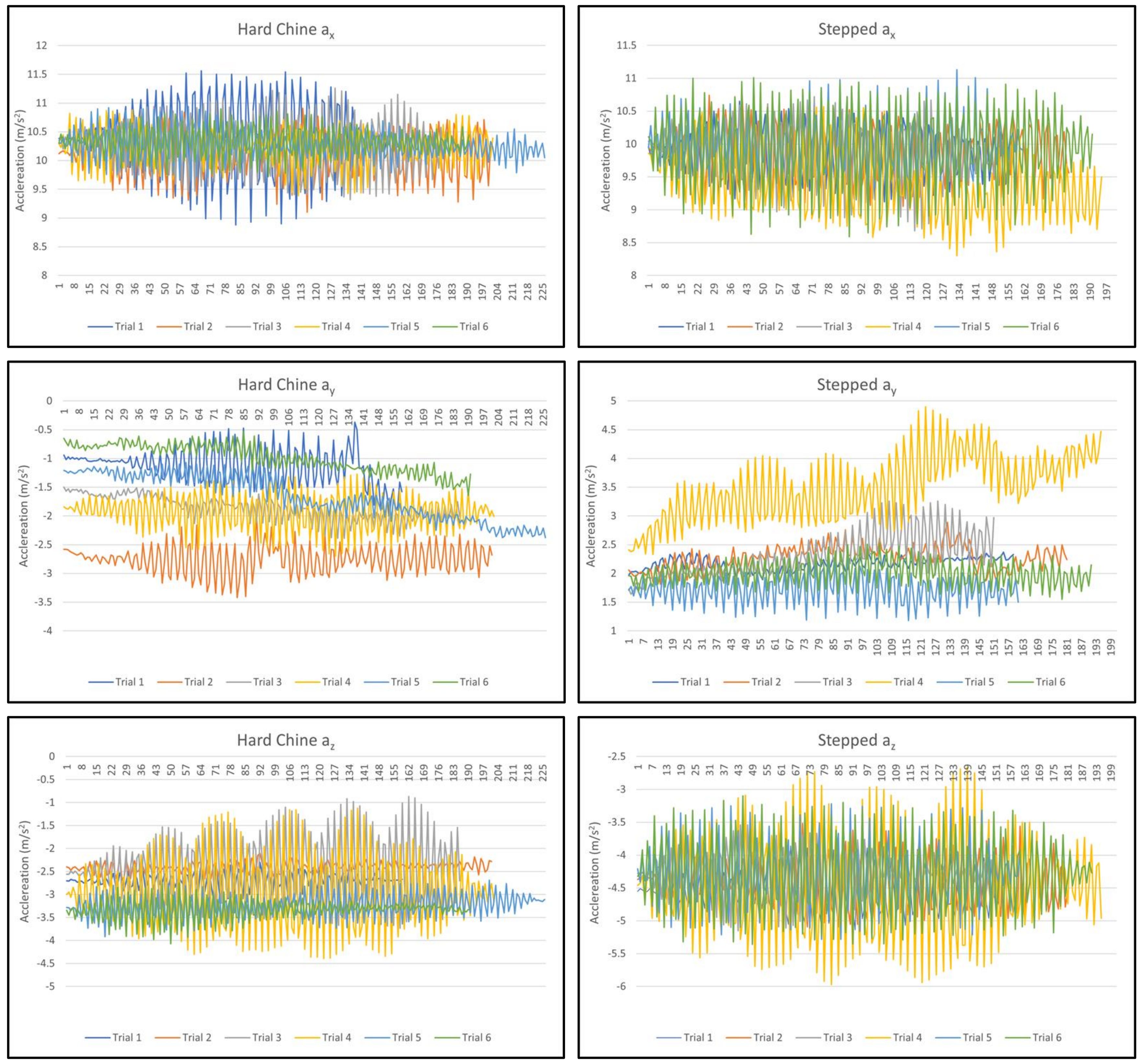


Fig. 3: Graphs of $a_x$, $a_y$, and $a_z$ (accelerations on the x, y, and z axes, respectively). Stepped $a_x$ appears to show a lot of randomness in the data. Hard Chine $a_x$ and Stepped $a_z$ appear to show less, though not insignificant.

## 4. Discussion:

The data collected during the six different trials for each of the two models certainly showed the differences in their performances. Both hulls showed similar x-axis accelerations through all of their trials, with some notable exceptions. For the hard-chine hull, trial 1 led to more forceful accelerations than the others, and for the stepped hull, the accelerations during trial 4 were overall lower than those for the other trials. For the y-axis accelerations, the hard-chine hull showed a lot of variation between each trial, while there was little variation between the accelerations for the stepped hull, with the notable exception of trial 4. I do not know why the y-axis accelerations are negative for the hard-chine hull and positive for the stepped hull, but that may have been due to the sensor being positioned slightly differently in each model.

While trials 4 and 5 led to large z-axis accelerations for both hulls, the hard-chine hull had consistently smaller accelerations than the stepped hull. This data confirms our observations that the stepped hull rolled much more intensely than the hard-chine hull did during every test. It also confirms our other observation, which was that both hulls were very stable during trial 6. That may be because the ratio of the length of the waves being generated to the length of the hulls allowed them to slip past more easily.

Overall, while the stepped hull experienced greater accelerations than the hard-chine hull, they were also more consistent over the six different trials. Clearly, the hard-chine hull is more stable at rest than the stepped hull. This is sensible, since it has a larger displacement, and stepped hulls tend to have stability advantages at higher speeds.The implication of these results is that if naval architects or buyers are looking for boats that will be stable at rest or low speeds, they should choose a hard-chine hull design over a stepped one. Consideration, though, should be given to the fact that, when encountering waves at rest, a stepped hull will react more consistently than a hard-chine hull will, no matter the size of the waves.

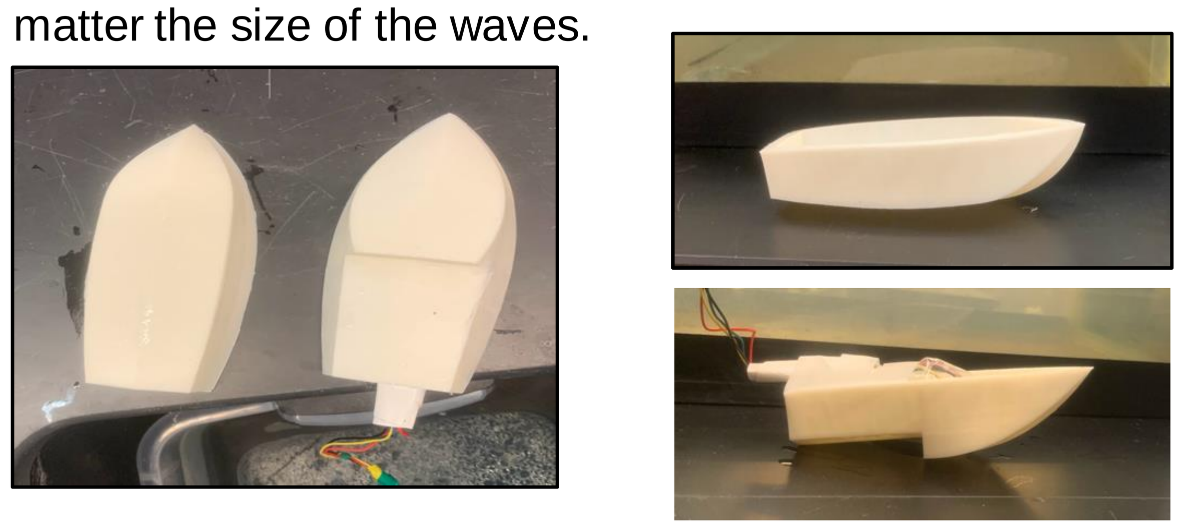

Fig. 4: Profile views of the two different hull shapes, hard-chine (left) and stepped (right).

## 5. TAKE HOME MESSAGE:

These changes in performance characteristics are becoming increasingly more important as boats are becoming faster and more powerful, since rough rides with heavy vibrations, especially in waves, can easily injure crew members.


## Acknowledgements:

I'd like to principally thank Mr. Futterman because, no matter how much he denies it, without his help I would not have been able to complete this project. I'd also like to thank Mr. Fallica, Ms. Peet, and Dr. Laungauni for their support and putting up with me being in the physics office at all hours. Finally, I would like to thank Mr. Higham for lending me his time and expertise, and for the construction skills I gained in his Stagecraft class.