MR44 and MID44 Grounding Tests
11 July 2001
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INTRODUCTION:

The Navy-44 grounding test described in the following report is part of an ongoing study by the United States Naval Academy. This study's purpose is to evaluate possible improvements to the original McCurdy and Rhodes design of the 44-foot sloops currently used by the Academy. It will help to ensure that the next fleet of 44-foot sloops used by midshipmen will surpass the already stellar safety record of the current design. Specifically, this experiment looked at altering the keel shape and the force necessary to free the boat after it has run aground. The MR44 keel is trapezoidal-shaped with nearly constant thickness from root to tip. The MID44 keel features a smaller trapezoidal keel with an IMS bulb that increases stability and decreases capsize resistance.

SETUP:

The 10.16 scale models that have been used in previous studies and reports were used in this experiment. A two-dimensional coastal wave tank located in the Naval Academy's Coastal Engineering Laboratory was used to simulate the running aground of the 44-foot sloops on a sandy bottom. Models were ballasted to their design displacement and a constant-force gravity tow system was used to tow the models down the tank. Altering the weight attached to the pulley system allowed us to vary the speed at which the groundings occurred. Two speeds were chosen for testing. The upper boundary speed range was 6 to 7.5 knots in order to provide data for normal operating speeds. The second speed was around 3 knots to analyze at low

Figures 1a & 1b – Basic Lab Setup

speed maneuvering. To evaluate the impact that the beach slope has on the force required to free a vessel that has run aground, 2 different beach slopes were looked at: 1 on 8 and 1 on 12. Figures 1a and 1b show the gravity tow system and tank used in the experiment. A purple paper clip located on the bow of the model indicates where the tow system connected to the model. Connection was established using an eyelet on the bow of the model through which the paper clip was fed. The weights in Figure 1a were used to load the pulley system in order to provide the constant towing force. Figure 1b on the right shows the two-dimensional tank with the beach that was used to run aground in the lower left-hand corner of the picture. A string tachometer was used to determine the speed the models attained, and a force sensor to determine the force necessary to free the model.

PROCEDURE:

Before the models were towed in the tank, we experimented to determine the weights necessary to achieve the desired boundary speeds. Prior to the first three runs of each speed and slope condition, the speed tachometer was zeroed. As the model traveled towards the beach, string pot positions were measured every 0.02 seconds. This data was collected by a computer and used to determine model speed just before impact. After each run, the force sensor was used to measure the peak force required to free the model from the beach. Each speed and slope condition was repeated for 10 trials. At right, Figure 2 shows a grounded model and the method in which the pull-off force was determined. The beach was raked after each trial to attempt to make the beach conditions similar for each trial.

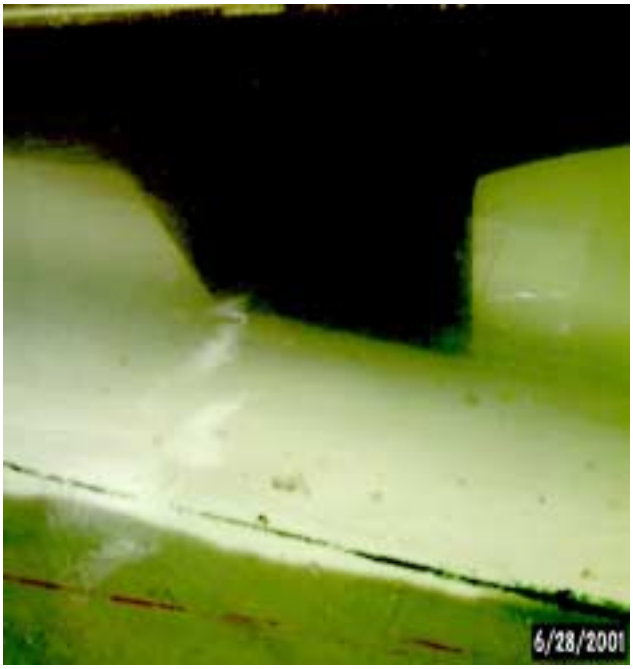
Figure 2 – Pull-off Force Measurement

After collecting all the speed and force data, a spreadsheet using Microsoft Excel was used to analyze data. The string tachometer data was used to determine model speed just before grounding by fitting trendlines to the data and then scaling to the full-size boat speed. Due to the lower resistance of the MID44 design, it was found to be faster when the same tow force was used for both models. This built-in a level of conservativeness

that might not be present in actual service. Force data was analyzed to determine the average force necessary to free the model, and was used as a direct comparison between the two keel shapes. For each condition the coefficient of variation was calculated to determine the confidence boundaries, and to see how much data scatter was present.

DISCUSSION OF RESULTS:

The overall objective of the experiment was to determine if there would be any appreciable change in the force required to free a 44-foot sloop if the keel shape was modified to a bulb shape and if it were to run aground. Figures 3a and 3b show



Figures 3a and 3b – Model keels aground (MR44 on the left and MID44 on the right).

the different keel shapes embedded in the beach. Clearly, the keel of the McCurdy and Rhodes design is embedded deeper in the sand compared to the bulbous keel design of the MID44 model. By observation and measurement, the models appeared to achieve equilibrium speed given the tank and tow conditions within about the same distance. Table 1 summarizes the findings of the force data for both speed and beach slope conditions.

The results of the experiment are pretty good. The slower speed towing cases show more data scatter. This is evident in the higher coefficient of variation values in Table 1. Greater coefficient of variation values for the low speed cases can be explained due to the fact that the force sensor used was very sensitive and the tow force present was significantly less than that for the higher speed case. Also, regarding the low speed cases, the stern of the models moved significantly more after the model had run aground. In each trial, there was a pretty noticeable wave that reflected off the beach and struck the model. The lower speeds had a smaller constant tow force pulling it on shore. Smaller tow force allowed the reflected wave to cause the stern move around more once

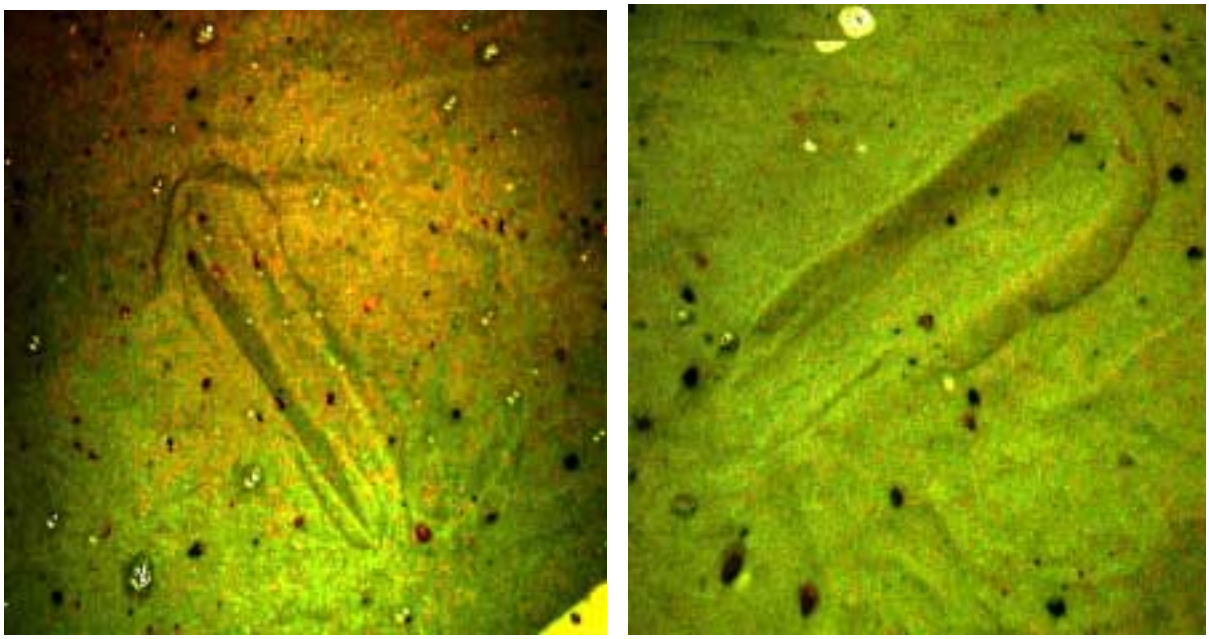
Slope = 1:8			
	Velocity (kts)	Avg Force (lbs)	COV
MR44	6.88	1.87	8.6%
MID44	7.43	2.01	8.2%
MR44	3.33	0.92	19.1%
MID44	3.4	0.56	18.0%

Slope = 1:12			
	Velocity (kts)	Avg Force (lbs)	COV
MR44	6.88	2.14	8.9%
MID44	7.43	2.14	16.1%
MR44	3.33	0.95	15.5%
MID44	3.4	0.91	21.5%

Table 1 –Data Summary

the model was aground. Typically, the stern would kick out some to the right if viewing the trial from the stern, and then return to a position close to its original position. The kick out distance varied from trial to trial but was not always present. More kick out lessened the pull-off force necessary to free the model because that extra movement providing some loosening from the sand for the keel.

An interesting finding to note is the furrow or shape left in the sand by the keels. Each keel left a distinct and unique furrow. The McCurdy and Rhodes keel design embedded deeper in the sand than the proposed keel. The MID44's furrow shape was flatter but wider. The flatter and wider furrower would suggest that this would be preferred because it does not appear to dig in quite as deep as the MR44's keel. Minimal entrenchment is favorable because that should lessen the force required to free the vessel. Figures 4a and 4b show the different furrow shapes.



Figures 4a & 4b – Keel Furrows (MR44's on the left and MID44's on the right).

Overall, there was not a big difference between the two keel shapes regarding the pull-off force necessary to free the model after it ran aground. There was one case in which the MID44 required more pull-off force than the MR44. This was the steep beach at high speed, when the MID44 was moving 0.6 knots faster. In the other three cases, the MID44 required the same or less force to pull off. Figure 5 graphically displays Table 1. It shows just how closely the models performed. The plot also includes the upper and lower confidence boundaries reflected from the coefficient of variation values for each condition.

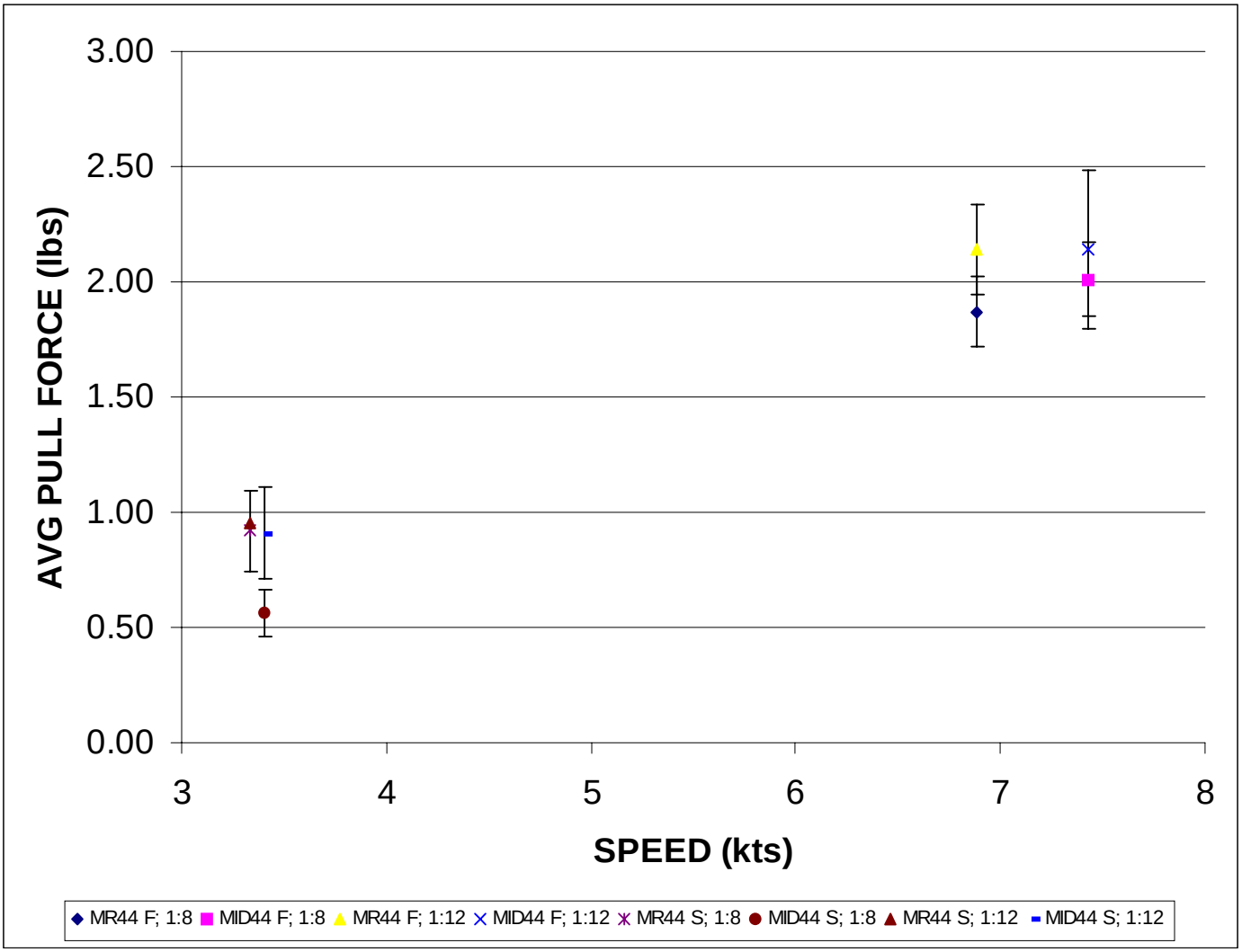


Figure 5 – Average Pull Force versus Speed Plot

There was one case in which one model clearly performed better. The MID44 required around half the force needed to free the MR44 in the 1 on 8 slow condition. In addition to the keel shape it is likely the 10% lower displacement of the MID44 contributed. Also, the wider stern on the MID44 tended to respond more to the waves, helping the keel to work out.

CONCLUSIONS/RECOMMENDATIONS:

Further investigation would help confirm the results of this test as well as reduce some experimental error. First, the tank used was only two-dimensional. The narrow channel may have amplified the reflected wave, which has a significant role in the slower condition trials. Second, vary the material of the beach. Sand was used in this experiment but other materials such as clay or mud represent a couple of the good and realistic alternative materials with which to test the two keels. Lastly, to increase measurement accuracy the tow force remained even after the vessel ran aground and was present when using the force sensor to determine the peak force necessary to free the model. Realistically, the tow force may not be present. Wind forces may act like the tow force did but wind forces are hard to predict and usually are not constant. Future investigations may want to look at the force readings after removing the constant tow force.

The simple objectives of this comparative experiment were achieved with fairly good and consistent results. On a whole, the models performed similarly. This suggests that the proposed MID44 bulbous keel shape would not alter what would happen if one of the current 44-foot sloops were to run aground. In fact, the results indicate that in some cases, it lends itself to perform better by minimizing the force required to free the sloop if it were to run aground. With the other advantages to be gained from a bulb keel it appears adopting one would be a design improvement.