

A Whitepaper for **High Performance Marine Engine Motion Simulator**

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Impact Testing on High Speed Planing Craft

Impact loading of high speed planing and semi-planing craft has traditionally been conducted in a single axis environment with a primary focus on hull structure, electronics and components, and to quantify human fatigue and injury. One area that has not been focused on is the deleterious effects of oil aeration within an internal combustion engine. In such engines, speed dependent or parasitic losses are linearly dependent on engine speed. In a standard non-impact operating environment, oil aeration losses typically amount to 2-3% of the total power production. These losses can increase significantly during operation in a dynamic impact environment, such as operating and maneuvering in open waters where the engine experiences constant changes in pitch, roll, and vertical accelerations. This can ultimately result in losses of 5-6% of an engine's total power output. Losses at these levels, especially as they apply to high performance engines, justify a serious investigation to quantify their magnitude and characteristics so that engine improvements can be made to reduce these losses. A test stand capable of simulating the planing craft's motion in a variable sea state environment is required to successfully complete this investigation.

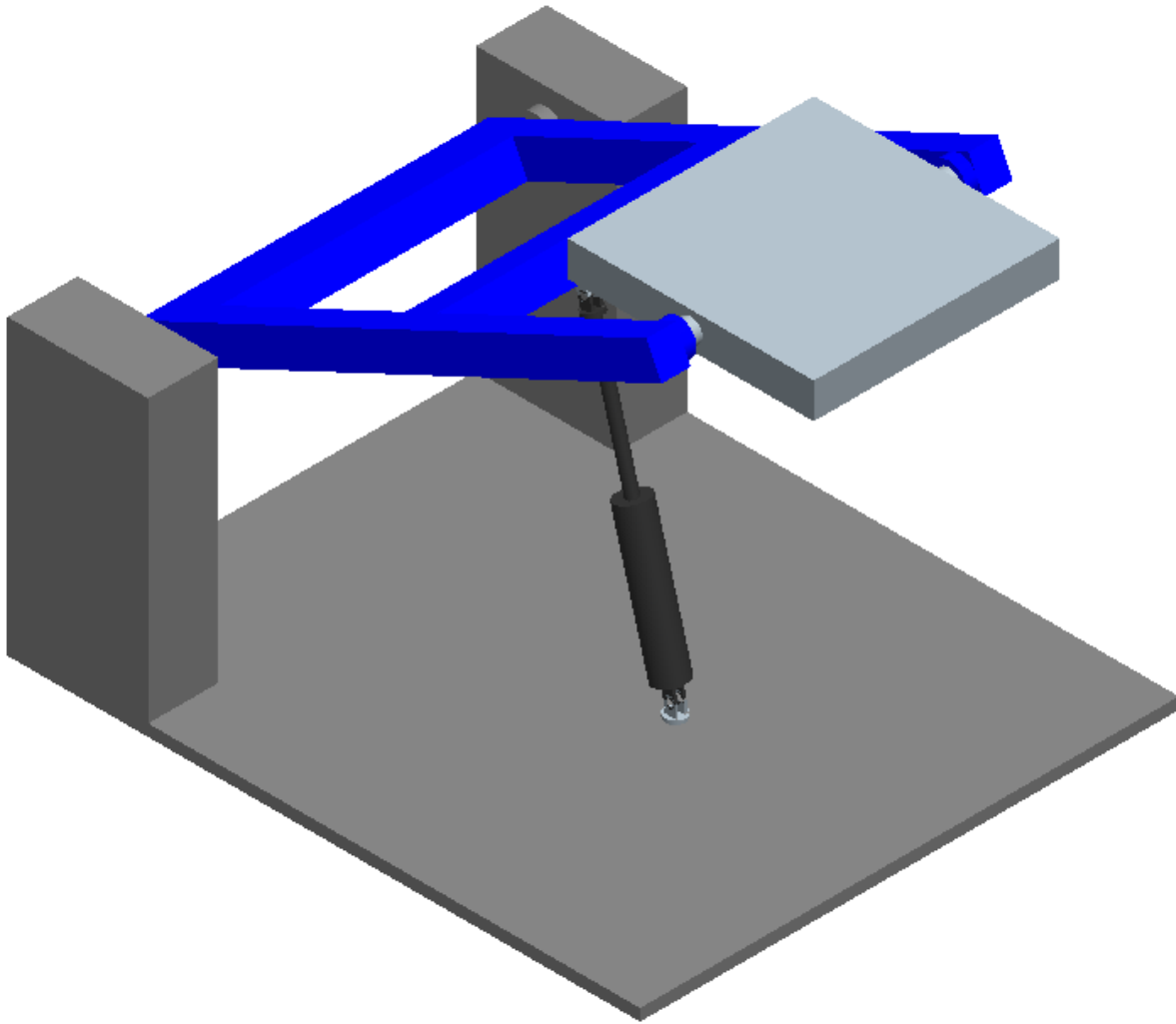
Wave Simulation Test Stand

SwRI can provide a test stand which is designed to simulate the roll and vertical motion experienced by a high performance marine craft operating in open water. The primary function of this test stand would be to simulate on a real time basis the characteristics of wave forms, including frequency, amplitude and position, and their interaction with a high speed craft. The operating envelope of such a test stand would be:

- $\pm 45^\circ$ roll
- Frequency: 0-10 Hz
- 50in vertical travel distance

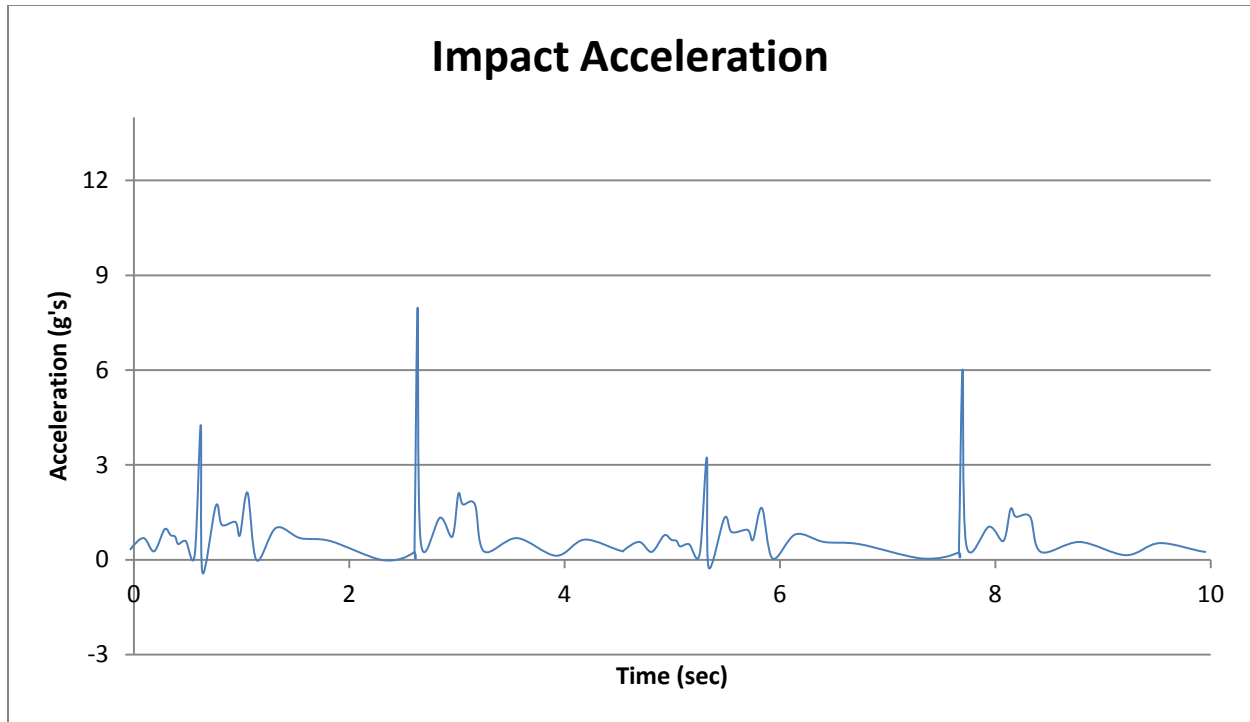


A conceptual model of the test stand is shown in the figure below.



The test stand motion will be driven by an ultra high speed hydraulic system working in conjunction with a real time programmable controller. Test profiles simulating variable craft speed, maneuvering, and sea state conditions could be input into the controller to produce vertical impact accelerations as shown in the graph below. Closed loop feedback control will be used to ensure the test stand motion matches that of the input motion profile using Hardware-in-the-Loop (HIL) testing protocols developed at SwRI. The effects of oil aeration would be recorded via specialized instrumentation and a high speed data acquisition system.

By applying these techniques it would be possible to quantify the bulk oil motion effects present in a reciprocating engine and provide an opportunity for oil system improvements including belly pans and oil pickup optimization. Improvements such as these could reduce engine fuel consumption and/or increase the range of operational angles that a craft could be operated without oil pump cavitation and engine oil aeration.



An impact event is a path function and must be simulated as such. One major drawback to current impact test stands is the inability to simulate the true magnitude of the drop condition. Peak impact accelerations can be met, but of significant interest are the velocities before and after impact which cannot be achieved. This can produce misleading results as a 4g acceleration at 30ft/sec can prove much more severe than a 20g acceleration at 0.1ft/sec. This test stand will overcome such inabilities by providing up to 50in of vertical travel distance in which adequate velocities can be achieved.

Southwest Research Institute's Past Experience

SwRI operates over 240 specialized dynamometer and load test stands at its San Antonio facility. Over the past 60 years it has conducted over 40 million hours of testing on these stands. Many of these stands have been involved in the investigation of oil aeration in engines.

SwRI operates numerous multiple axis and high hydraulic actuator count load test stands inputting complex load profiles on such equipment as aircraft wings, building structures and telecommunications equipment. SwRI has actively worked on numerous liquid sloshing problems in tanks such as in liquid propellant used in satellites, oil tankers and fire trucks. Studies have included investigations into frequency, planar motion and first and second order effects. SwRI operates numerous Hardware-in-the-Loop test stands used to evaluate engines, transmissions, powertrain components, and hybrid electric drivetrains.