Effect of hull gap on pressure distribution under PAR platform

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Introduction

Amphibious vehicles have many applications for the military and commercial industries. The power augmented ram vehicle (PARV) is a new concept of amphibious ground-effect craft which has several advantages over traditional air-cushion vehicles and wing-in-ground craft [1]. The PARV is supported by a high-pressure air cushion, formed by decelerating jets injected by front propulsors under the platform. In practical PARV operations, it is expected that a non-zero hull-ground gap will be present in most operational modes.

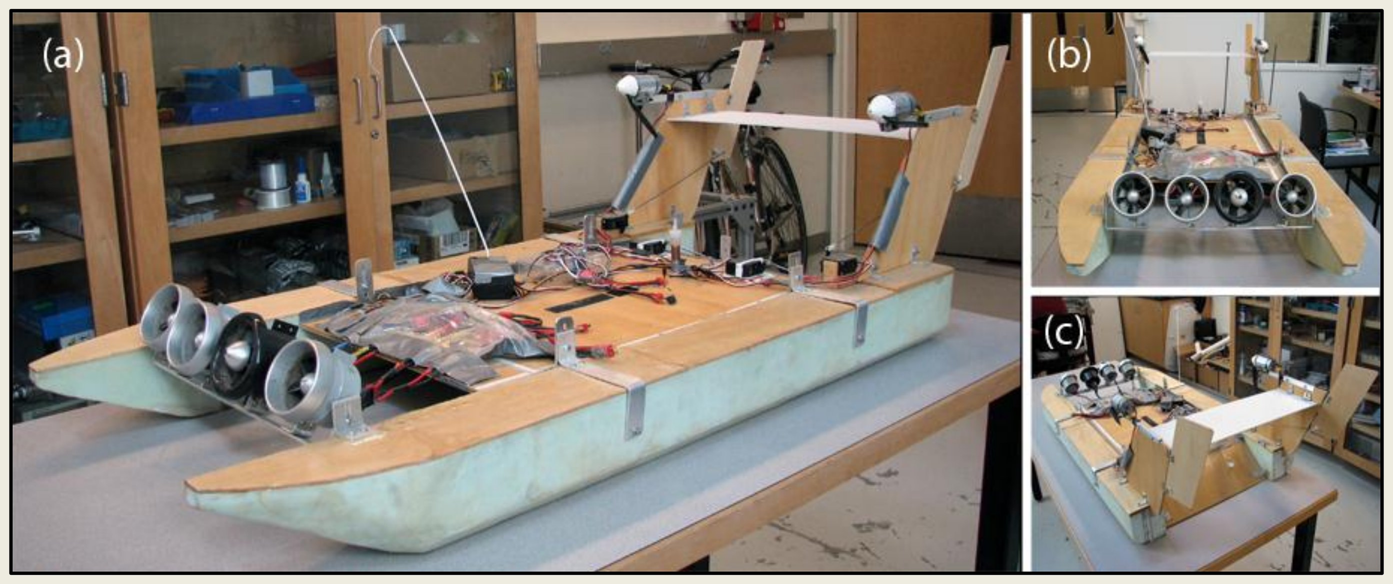

Figure 1. (a) Profile, (b) front, and (c) rear view of model PARV.

Objectives

- To study the effect of hull gap on the PARV pressure distribution.
- To correlate idealized jet theory with experimental results.

Experimental Setup

A 80-cm-long platform, including a 17-cm-long stern flap, was mounted onto two side hulls to create a channel for PAR flow. Flow is emulated by a fan connected to a nozzle. Pressure measurements were taken from nine pressure taps along the platform centerline and four taps along the width. The effect of three separate cases on the pressure distribution was studied: (i) variable gap between hull and ground, (ii) variable pitch, and (iii) variable roll.

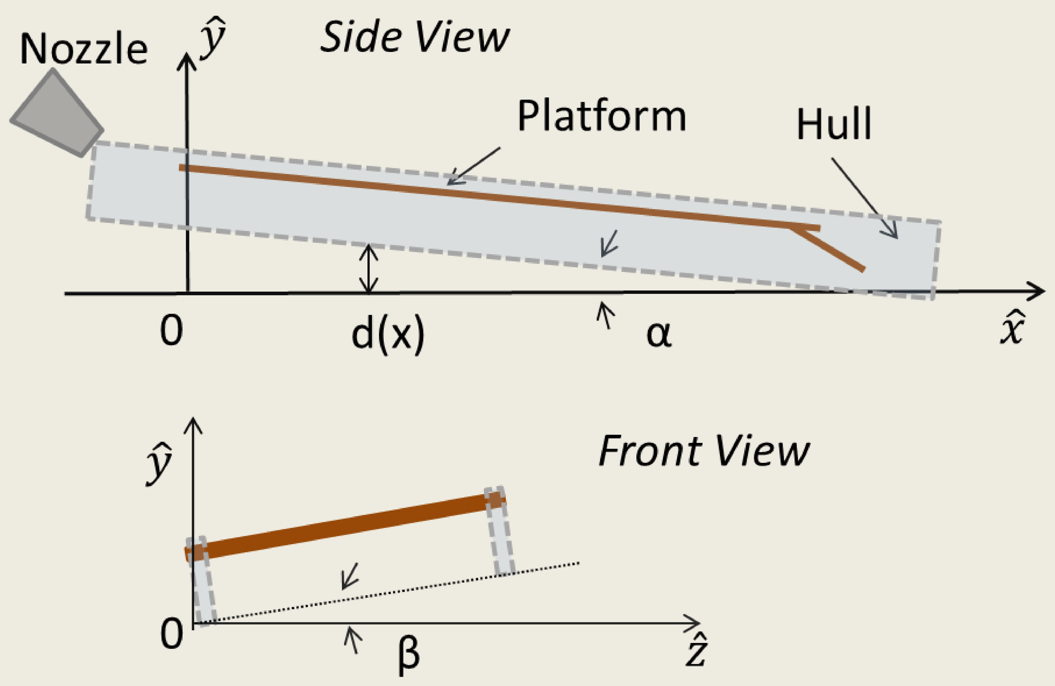

Figure 2. Schematic of Experimental Setup

Experimental and Theoretical Results

Experimental and theoretical (dashed lines) pressure coefficients were plotted against platform length

$$C_p = \frac{p_g(x)}{0.5\rho u_n^2} \quad (1)$$

where $p_g(x)$ is the gage pressure, ρ is the density of air, and u_n is the nozzle velocity.

- The pressure under the platform was greatest with no hull gap .
- Significant reductions in pressure at finite gaps were due to air leakage under the hull (Fig. 4 – 5).
- The pressure decreases sharply in the region of the flap due to flow acceleration in the converging channel.
- The upward slope of C_p at finite hull gaps is due to flow deceleration as the flow reaches the flap.

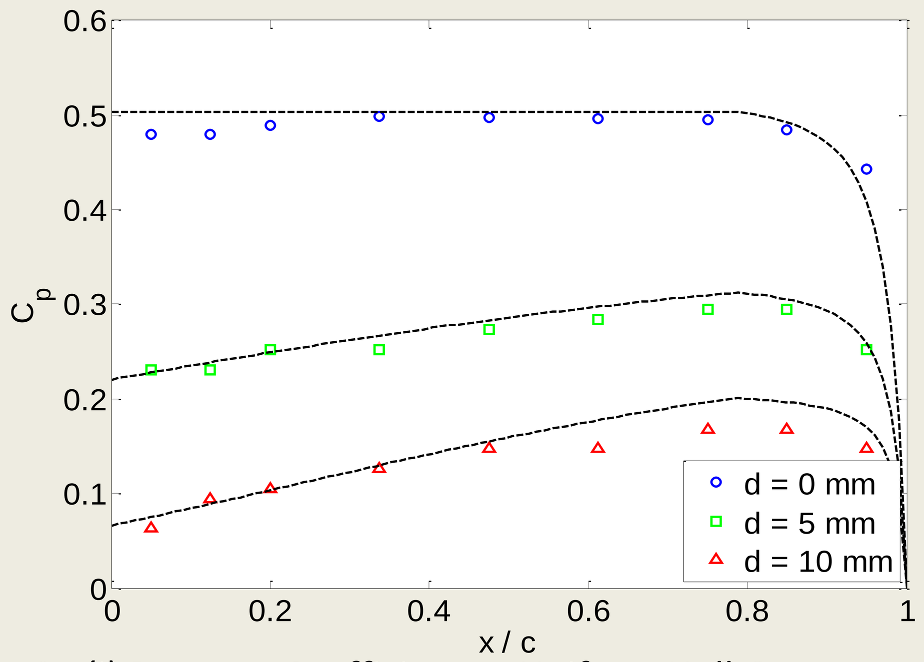

Figure 3. (i) Pressure Coefficient at Uniform Hull Gap

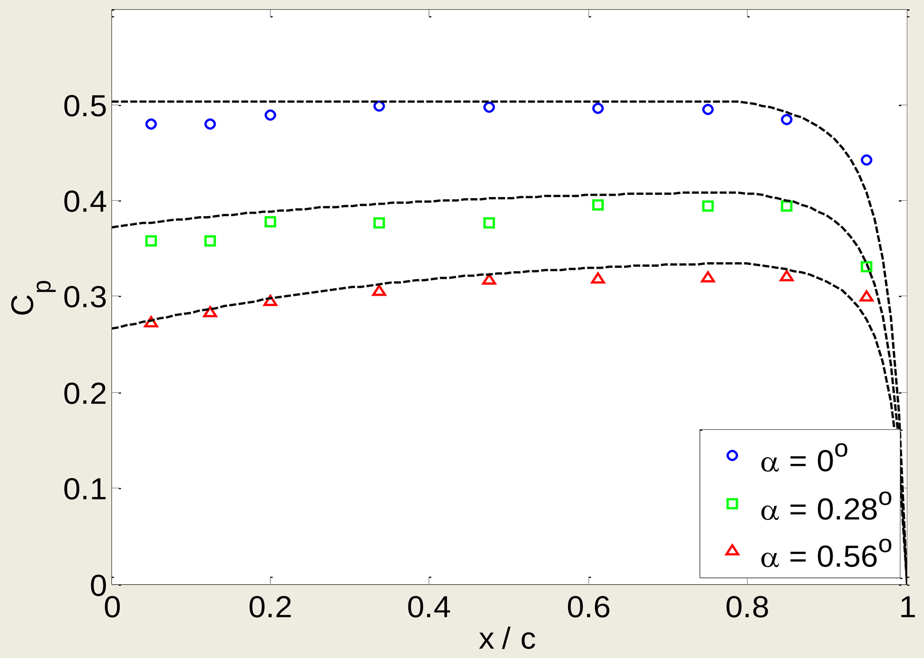

Figure 4. (ii) Pressure Coefficient at Variable Pitch Angle

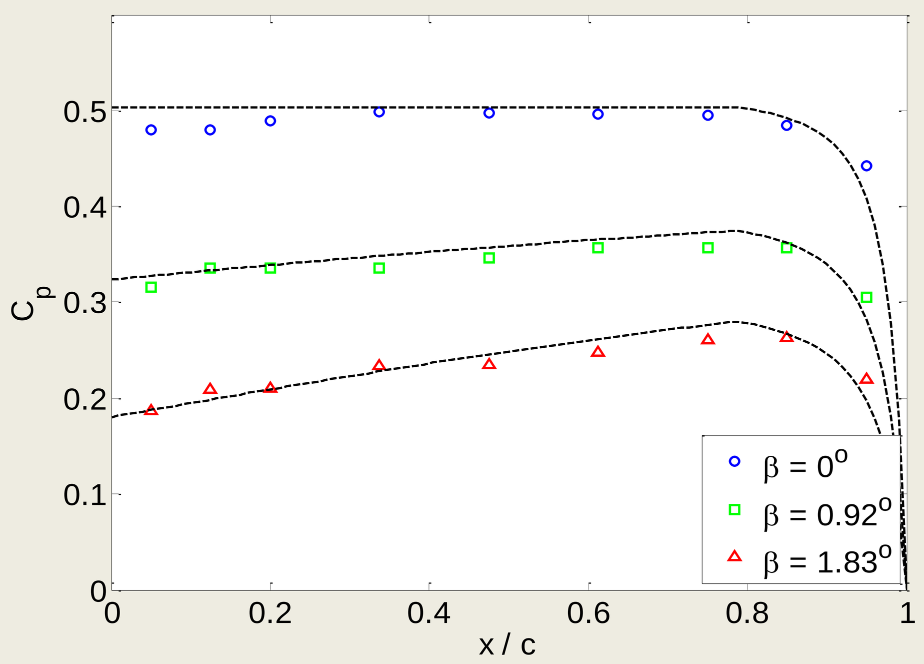

Figure 5. (iii) Pressure Coefficient at Variable Roll Angle

Modeling

The one-dimensional inviscid flow model for a platform with hull clearances in the extreme ground effect can be used to estimate the pressure distribution along a PAR platform [2].

$$b\frac{d}{dx}[h(x)u(x)] + 2d(x)\sqrt{U_j^2 - u(x)^2} = 0 \quad (2)$$

where b is the platform width, $h(x)$ is ground and platform distance, $u(x)$ is the velocity in the channel, $d(x)$ is the gap between hulls and the ground, and U_j is the velocity at the channel entrance.

The boundary condition is defined at the flap trailing edge and follows from Bernoulli's relation.

$$u(c) = U_j \quad (3)$$

Due to non-uniform turbulent jets, jet expansion, and variations in U_j, an empirical relation is introduced to relate the nozzle velocity u_n to U_j.

$$U_j = 5.2u_n\left(\frac{t_n}{h_{avg}}\right)^{2.4} \quad (4)$$

Equation (2) was solved numerically to find $u(x)$. The pressure coefficient was found using the Bernoulli equation

$$0.5\rho U_j^2 = 0.5\rho u(x)^2 + p_g(x) \quad (5)$$

which was used in equation (1) to find the theoretical pressure coefficient.

Conclusion

Experimental results have shown the substantial effect of a finite hull gap height on the reduction and re-distribution of the pressure under the PAR platform. Large decreases in the pressure and increasing trend of the pressure coefficient in the front part of the platform relative to the nominal case without gaps were found. The idealized inviscid jet model with empirical corrections was shown to predict experimental pressure distributions.

References

[1]Matveev, K.I. (2009) 'Study of power augmented ram vehicles', *Proceedings of SNAME Annual Meeting*, Providence, RI.

[2]Rozhdestvensky, K.V. (2000) *Aerodynamics of a Lifting System in Extreme Ground Effect*, Springer-Verlag, Heidelberg, Germany.