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Short Communication

# Static performance of power-augmented ram vehicle model on water

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ABSTRACT

An experimental parametric study of a novel air-assisted platform-type model called power-augmented ram vehicle is described. The zero-speed regimes of the model over the water are investigated. The recovered thrust, pressure underneath the platform, and the model attitude are recorded for variable system geometry, loading conditions, and propulsor thrust. The stern flap under the model platform provides an effective mechanism for controlling the thrust recovery and the air-jet-induced lift. Unstable behavior of the model is found at sufficiently high levels of the propulsor thrust.

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## 1. Introduction

Power-augmented ram vehicles (PARV) belong to a new class of air-supported amphibious craft. One possible PARV schematic is shown in Fig. 1a. The vehicle structure includes a platform positioned between two side hulls and a stabilizing stern wing attached to vertical struts. There are two different propulsion systems. The first consists of the air (or exhaust gas) jet sources mounted on the pylon in front of the platform; and the second involves air-based propulsors arranged on the stern struts.

At low speeds, the vehicle weight is supported by the hydrostatic force acting on the hulls (or by static reaction on the bottom of hulls in contact with solid ground) and by the pressurized dynamic air cushion under the platform. The air cushion is formed by decelerating and expanding air jets produced by the front propulsors and directed underneath the platform. The position of the stern flap on the lower side of the platform regulates the air-cushion pressure and the recovered thrust. The dynamic air cushion does not employ any flexible skirts or fences. This type of air cushion, which is the main element of the power-augmented ram system, has been previously employed on full-scale wing-in-ground (WIG) craft as takeoff assistance means (Maskalik et al., 1998). One of the tests with a PAR-WIG model is described by Krause (1977). The word ram in the PAR abbreviation originates from the dynamic-to-static pressure conversion that occurs in the airflow decelerating in the channel under a ground-effect wing or platform, and power augmentation means that momentum of the incident airflow is increased by propulsors located in front of the wing.

At high speeds, a significant fraction of the PARV lift is contributed by aerodynamic forces acting on the platform due to forward motion of the vehicle. This lift component is sensitive to the platform attitude and can be augmented in the ground effect. The efficient stern propulsors become the main thrust source at high speeds. The orientation of the front propulsors can be changed to realize more thrust (rather than PAR support). In the case of jets blowing above a wing-shaped platform, the wing lift can be increased due to pressure reduction on the upper side of the wing.

The PARV advantages over air cushion vehicles (ACV) include much higher cruising speeds, higher payload-to-displacement ratio, and the absence of flexible skirts that require frequent maintenance. Different from the WIG craft, PARV is more compact with higher payload-to-area and payload-to-displacement ratios and more stable and safer craft due to retained contact with the ground surface.

Concepts similar to PARV have been discussed previously (Gallington, 1987; Kirillovykh and Privalov, 1996). However, practical development of these ideas was very limited. At the present time, there are growing needs of navies and offshore industry for compact, high-payload, fast, and amphibious transportation means. These challenging requirements can be met by the PARV technology. Prototype model construction and testing of these new craft have been recently initiated (Matveev and Malhiot, 2007; Matveev, 2008).

This paper focuses on the static performance of a PARV model on the water. The main objective of this investigation is to generate an experimental database with important PARV variables under various conditions, which can be used for the design of PARV craft and for comparison with future CFD studies of PARV aero-hydrodynamics.

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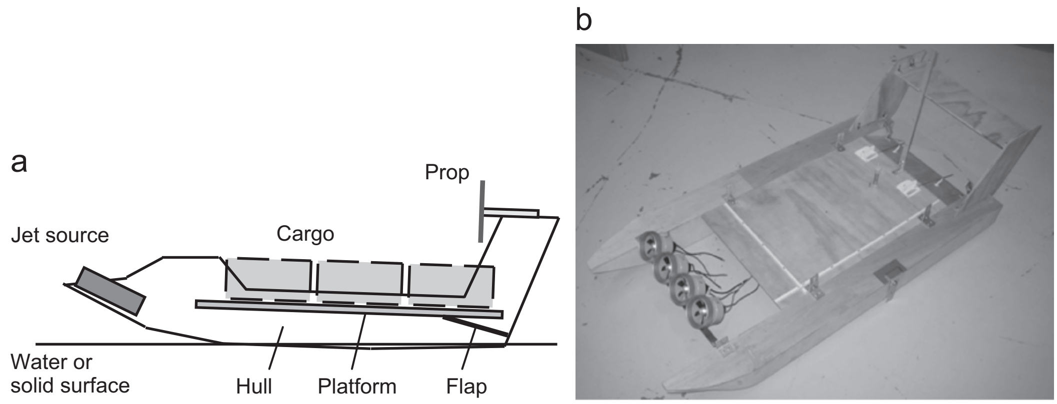


**Fig. 1.** (a) Concept schematics of power augmented ram vehicles and (b) scale model of PAR vehicle.

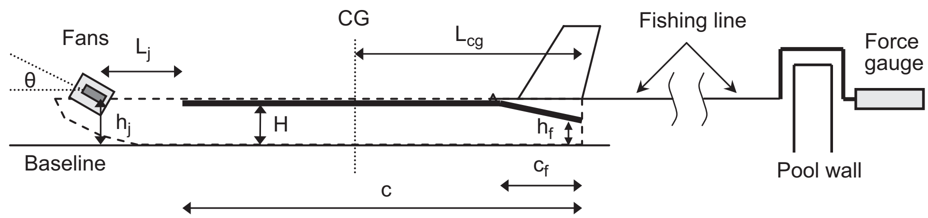


**Fig. 2.** Principal geometrical parameters of the model. CG, center of gravity vertical line; BL, hull bottom horizontal baseline.

## 2. Experimental setup

A model of PARV was constructed as shown in Fig. 1b. Two side hulls were made of Styrofoam and covered by fiberglass. The hull decks, platform, vertical struts, and stern wing were made of wood. The front propulsor pylon and various connectors were made of aluminum plates and angles. Bolted connections allowed us to easily change positions of the model structural elements. This model was also designed for the self-propelled radio-controlled operations, although no radio-controlled equipment (except for the front motors) was employed in the tests described here.

The main system parameters are illustrated in Fig. 2. The fixed parameters have the following values: model length $L = 114$ cm, platform chord (length) $c = 80$ cm, flap chord $c_f = 16$ cm, platform beam $b = 40$ cm, and overall model beam $b_m = 60$ cm. The default variable parameters include the zero pitch of the platform (with respect to the hull baseline) and the platform height $H$ (by default $H = 10$ cm), which is the vertical distance between the platform lower side and the hull bottom (baseline) as shown in Fig. 2. In one test $H = 7$ cm was installed, and in another test a pitch angle $3.7^\circ$ was assigned to the platform with the distance between the platform leading edge and baseline 11 cm. The distance between the flap trailing edge and the baseline $h_f$ was one of the primary variable parameters, assigned to values 0, 3, 6, and 9 cm.

The model default mass with front propulsors was $M = 4.3$ kg. In some tests, the model was ballasted with weights up to 8.1 kg. The default center of gravity $L_{cg}$ was 48.5 cm from the trailing edge of the platform. The ballast was also moved along the model, which led to the change in $L_{cg}$.

Three positions of the propulsor pylon were studied, as listed in Table 1. $L_j$ is the horizontal distance from the center of the propulsor exit area to the platform leading edge, $h_j$ is the vertical distance from the same point to the hull baseline, and $\theta$ is the inclination of the propulsor centerlines to the horizontal plane.

Four 6.6 cm inside diameter MTH ducted fans with six-blade carbon fiber propellers driven by Kavan long speed 400 electric motors were employed as propulsors. The motors were wired in series and connected to a regulated stationary electric power supply. The thrust of the propulsion system $T_p$ was a primary variable parameter in tests. It was controlled via applied voltage, which was assigned to values 15, 25, 35, 45, and 55 V. The thrust of the separated propulsion system in the free air was measured by a force gauge holding the pylon with fans, similar to an arrangement used by Matveev and Malhiot (2007). The propulsor thrust measurements are presented in Table 2. The thrust recordings of the separated propulsion system did not change significantly (within 3%) when this system was placed at the locations where it was mounted in the water tests.

**Table 1**
Propulsor arrangements

| | |
|---|---|
| A | $L_j = 16$ cm, $h_j = 15$ cm, $\theta = 30^\circ$ |
| B | $L_j = 18.5$ cm, $h_j = 9.5$ cm, $\theta = 15^\circ$ |
| C | $L_j = 18.5$ cm, $h_j = 9.2$ cm, $\theta = 22^\circ$ |

**Table 2**
Thrust measurements of the separated propulsion system versus applied voltage

| Voltage (V) | 15 | 25 | 35 | 45 | 55 |
|---|---|---|---|---|---|
| Thrust (N) | 1.1 | 3.1 | 5.8 | 8.9 | 12.3 |

The zero-speed tests of the PARV model on water were conducted in the pool of width 120 cm and length 240 cm. The water depth in the pool was 25 cm. The model was tested at the zero speed, no waterborne propulsion was employed, and the jet exit under the flap was not affected by the pool back wall. Therefore, it was concluded that the influence of the finite pool size on the static model performance was negligible. At small and moderate values of the applied thrust, significant water motions were mainly restricted to the area under the platform and to close proximities of the bow and stern parts of the model. At high values of thrust, especially when the model became unstable and

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