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HOVERCRAFTS - AN OVERVIEW Part II: BASIC CONSTRUCTION PRINCIPLES, CLASSIFICATION, ADVANTAGES, DISADVANTAGES

BY

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Abstract. This is the second part of the hovercrafts study series. The first part of this study includes the hovercraft description and a brief history. This article presents information on the first design principles of air cushion vehicles, criteria for hovercraft classification and advantages and disadvantages of using these types of vehicle. The authors present less known information on first two constructive models that have had a major impact on the development of the air cushion vehicles and emphasize the differences between them. The classification of hovercrafts is performed taking into account some of the most important criteria and includes the presentation of the most known constructive forms of air cushion vehicles. Some of the most important hovercraft classes that are still in active service or used in the military field are presented in tabular format, the information being compiled from various sources.

Keywords: open plenum theory; momentum curtain theory; hovercraft classification; specific applications; advantages and disadvantages.

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1. First Theories on the Development of Air Cushion Vehicles

As mentioned in the first article on this study, the concept of air cushion vehicles (ACV) dates back to the 18th century. The most well-known theories of studying the airflow in the inner cavity of an air cushion vehicle are open plenum theory and momentum curtain theory.

In order to achieve a suggestive picture of the concept of the two theories, Fig. 1 presents the constructive models defining the two cases. The images depict both constructive components and forces that occur during the airflow operation.

The main difference between the two constructive models is the buoyance tank. This component revolutionized the area of ACVs, generating better designs with exceptional functional features.

The open plenum theory constructive model (Fig. 1 – left) includes only the hull of air cushion vehicle and air source. The air source serves to feed the inner cavity of the hull and may be an axial / centrifugal fan or blower. Shortly after air source starts, the inner cavity pressure becomes larger than atmospheric pressure, leading to the lift of the entire assembly from the running surface, thus creating an air cushion. For this concept, the air source must maintain a constant flow due to fluid leakage at the periphery of the vehicle. This concept described resembles the idea of Emanuel Swedenborg in 1716.

Because this design requires a source of constant airflow to compensate the peripheral leakage, engineer Christopher Cockerell filled in 1956 a patent to improve this concept by successfully designing a constructive hull that reduced the friction between the hull and the running surface (Cockerell, 1968). This concept is known today as the momentum curtain (Fig. 1 – right).

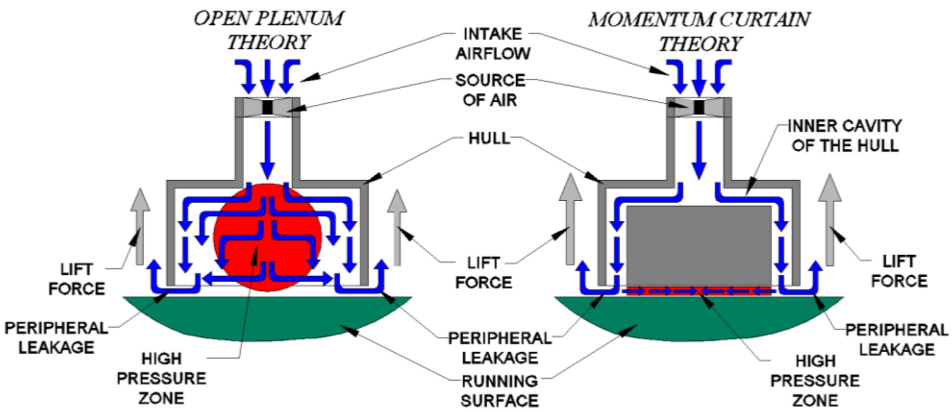


Fig. 1 – Open plenum theory and momentum curtain theory (figure adapted from Chow, 2012).

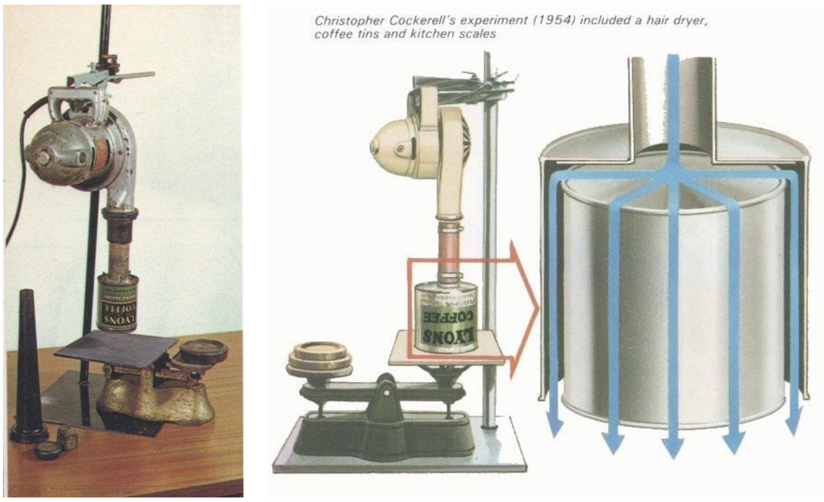


Fig. 2 – Principle scheme of the experiment conducted by Christopher Cockerell (Sassarini-Bustamante, 2009).

The innovation consists in introducing a buoyancy tank, thus generating an airflow between the inner surface of the hull and outer surface of the tank, that applies a higher pressure on the running surface than in the plenum theory case. This also leads to a slight increase in the lifting force, which improves the performance of these types of vehicles.

Cockerell assembled two tin cups of different diameters and used a hair dryer to create an airflow within the interstice between them, Fig. 2. He noticed the creation of a thin air cushion that lifted the whole assembly few millimeters from the ground (Yun and Bliault, 2012).

2. Main Criteria for Hovercraft Classification

Considering that hovercrafts had different constructive forms over time and were employed in various applications, Fig. 3 summarizes the main criteria to classify these types of vehicles.

The first criterion for hovercraft classification is their quality. Thus, there are three types of hovercrafts (Mohamed Noor *et al.*, 2016):

– amphibious
– non-amphibious
– semi-amphibious

In general, the ACVs have amphibious qualities, due to the fact that this type of vehicles may run on different types of surfaces such as: ground, ice, water (inclusive shallow water), swamp, mud, vegetation, sand, logs and debris, flood plains etc (Griffon Military & Paramilitary).

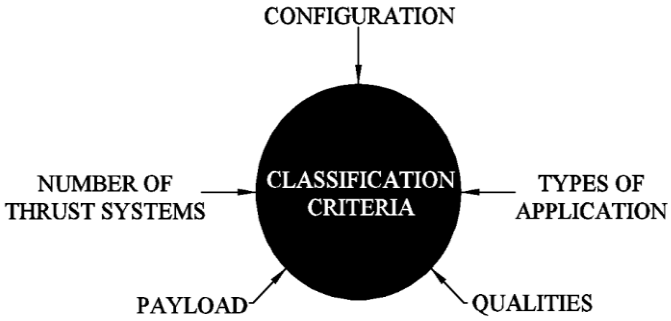


Fig. 3 − Main criteria for hovercraft classification.

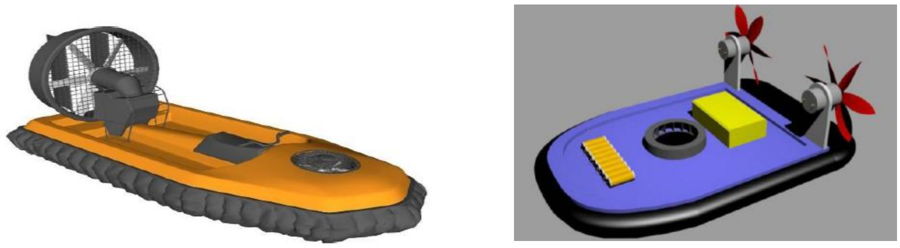
Unlike ACVs, the category of surface effect ships has non - amphibious qualities, because this type of vehicles can only operate on water due to the two components called sidewalls.

The vehicles in semi-amphibious hovercraft category are characterized by the fact that are limited to travelling on water (Chow, 2012). An eloquent example of semi-amphibious hovercraft is the model Vosper VT-1 (Paine and Syms, 2012).

The second hovercraft classification criterion (for ACV subcategory) is payload (Sassarini-Bustamante, 2009), Fig. 4. The difference between the two vessels consists in that light hovercrafts have carrying capacities below 9.8 kN while heavy hovercrafts have a carrying capacities that exceeds this values (Herring and Fitzgerald, 2006).

The number of thrust systems is the third criterion for hovercrafts classification (for ACV subcategory). In Fig. 5 (Anandhakumar *et al.*, 2015) are represented the constructive models with only one thrust system (a) and of several thrust systems (b).

Fig. 4 – Classification of hovercrafts according to the payload.



a *b*

Fig. 5 – Classification of hovercrafts according to the number of thrust systems.

The fourth criterion for hovercrafts classification (for ACV category) is their constructive form. Considering the fact that various ACVs have been built over time and have different configurations, in Fig. 6 only three constructive forms, which are currently known, are presented.

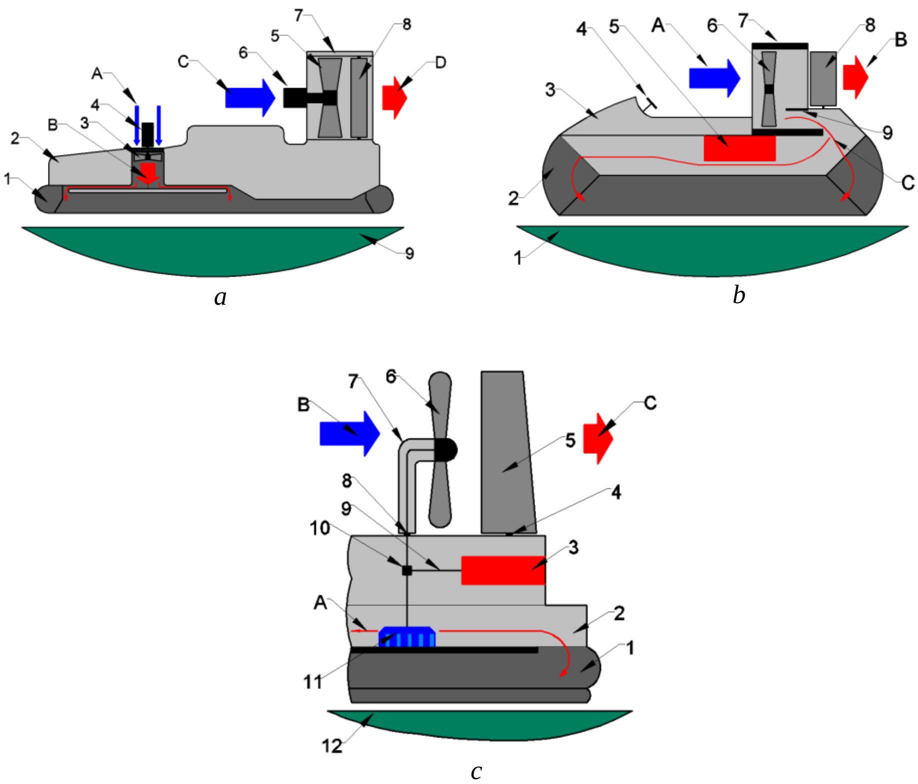


Fig. 6 – Different types of ACV (adapted from Anguah and Szapiro, 2009).

The first constructive form of ACV has a two-system configuration: one generates lift force and one thrust force, Fig. 6*a*. The components denoted are flexible skirt (1), hull (2), fan / blower for lift force (3), engine of fan 3 (4), fan / propeller for thrust force (5), engine of fan / propeller 5 (6), thrust duct (7), rudder (8), running surface (9). Also, the airflow are at the lift fan inlet (A), airflow required to obtain lift force (B), airflow at the thrust fan inlet (C) and airflow required to obtain thrust force (D).

The second constructive form is the ACV that has only one system to achieve both the required lift force and thrust force. This configuration, shown in Fig. 6*b*, describes the running surface (1), flexible skirt (2), hull (3), steering (4), fan/ propeller engine (5), fan or propeller (6), thrust duct (7), rudder (8) and splitter plate or lift / thrust divider (9). The airflows depicted are at the fan inlet (A), airflow required to obtain thrust force (B) and airflow required to obtain lift force (C). When compared to the first configuration presented, it can be seen that the lift / thrust divider is the innovative element that controls both the amount of airflow entering the thrust system and the amount of air entering the lift system.

The last configuration of ACV, shown in Fig. 6*c*, has been used in the first air cushion vehicles, similar to the SR.N4. The elements described are flexible skirt (1), hull (2), propeller 6 engine (3), rudder bearing (4), rudder (5), propeller (6), pylon (7), pylon bearing (8), drive shaft (9), gearbox (10), centrifugal fan (11) and running surface (12). The airflows are required to obtain lift force (A), airflow at the propeller inlet (B) and airflow required to obtain thrust force (C).

Regardless of the constructive form, it is possible to attach wings on some hovercraft models, allowing them to fly at low height above ground, making these vehicles unique in the world (Universal Hovercraft).

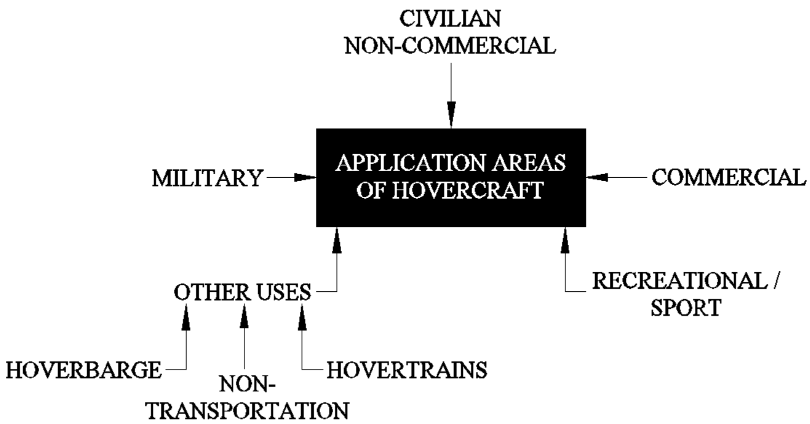


Fig. 7 – Classification of hovercrafts according to general area of application.

The last presented classification of hovercrafts (ACV subcategory) is by type of application. The continued development of ACVs led to the emergence of unique applications, due to the amphibious qualities already mentioned. Figure 7 presents the main areas where hovercrafts are generally used (Yun and Bliault, 2000).

Table 1 compiles data from various sources (Russell, 1986; Griffon Military & Paramilitary) to provide an alphabetical list of hovercraft uses. It may be inferred, as mentioned in the first paper of this series as well, that most important uses and operations are in the military area. Table 2 details some hovercraft models that were or still are in active service (Crawford, 2010; Taghipour and Zarrabi, 2012).

3. Advantages and Disadvantages Regarding the Use of ACVs

ACVs are means of transport that are still under development. The constructive models were periodically improved and currently display some superior qualities compared to the other means of transport.

Table 3 and Table 4 synthetically present the main advantages and main disadvantages, respectively.

Table 1
Areas of Use of Air Cushion Vehicles

Purpose of use	
agricultural spraying	military service
access from water for no boat dock areas	mine counter measures
bird / wildlife watching	mosquito abatement
cruising	oil spill clean-up
dive team recovery missions	port authorities
drug enforcement	racing
exploring remote areas	seismographic surveying
fast attack	sight - seeing
fishing anywhere	survey work
flood patrol assessment and management	film companies
forestation	victim retrieval over inaccessible surfaces
hunting	wildlife retrieval over inaccessible surfaces
hydrographic surveying	weapons platform
medical evacuation & humanitarian aid	

Table 2

Hovercrafts Used by the Military Domain

No.	Military marine nationality	Hovercraft description (class / type / name)	Application
1.	United States Navy	LCAC	Primary role of transporting both military equipment and personnel from ships to operations ashore
2.	Japan Maritime Self-Defence Force	LCAC	
3.	Soviet Navy / Russian navy	Gus-class ACV	Assault and logistic missions
		Lebed - class ACV	Assault landing and logistics - over - the - shore
		Tsaplya - class LCAC	Assault
		Czilim - class ACV	Border patrol
		Zubr - class LCAC	Sealift amphibious assault units and for transport
4.	Iran Navy	Tondar (SRN-6) hovercraft	Combat vessels
		Wellington (BH.7) hovercraft	
		Younes 6 hovercraft	Logistic mission and patrolling
5.	Finnish Navy	Tuuli hovercraft	Not entered into active service and decommissioned in 2013

Table 3

The Main Advantages of Using Air-Cushion Vehicles

No.	Advantages
1.	Have amphibious qualities
2.	Some types of ACVs can float on the water when stationary
3.	Lead to the preservation of the natural habitat
4.	Can move on sea mines (due to the low air cushion pressure)
5.	May be used for application not otherwise specified in other means of transport
6.	Are faster that some conventional marine vessels
7.	Can be launched from different ship types and independent of harbors and piers

Table 3
Continuation

No.	Advantages
8.	Can be used to shorten routes
9.	Can cross rivers, go upstream and downstream
10.	Some models of ACVs are equipped with cabin for crew protection
11.	Can be used in hard-to-reach places
12.	Have greater access to seaside areas than conventional ships
13.	Operating costs may be lower than other means of transport (*e.g*., helicopter)

Table 4
The Main Disadvantages of Using Air-Cushion Vehicles

No.	Disadvantages
1.	The noise produced by the thrust system and lift system
2.	Predisposition to destruction of the flexible skirt or segmented skirt
3.	Involve high maintenance costs
4.	Require qualified personnel to carry out maintenance
5.	Exhibit a low stability under a combined action of wind and waves
6.	Cannot run on a highly inclined slopes
7.	Cannot run on highly uneven ground
8.	Have a fuel consumption higher that some conventional ships
9.	Have handling problems at very high operating speeds

4. Conclusions

This paper continues the series on informative articles on hovercrafts. From the explanations included, it may be observed that the momentum curtain has greatly influenced the development of these types of vehicles, breaking the barrier that made this vehicle concept stagnant. The discovery of the phenomena that led to this innovation could be accomplished with objects used in everyday life. Thus, simple things may influence an evolution.

Regarding the constructive shapes, those presented here are the most well-known in their categories. But some constructive models, especially after the development of first ACVs (such as SR.N1), had impressive constructive shapes that differ greatly from classic ones (an eloquent example would be ACV Sormovich).

Multiple areas of use for ACVs demostrate that the general public is not losing interest in using this concept. Both the advantages and disadvantages of these vehicles place them in a special category, always being able to replace almost any other means of transportation with this engineering masterpiece.

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AEROGLISOARE - O PREZENTARE GENERALĂ
PARTEA a II-a:
PRINCIPII CONSTRUCTIVE DE BAZĂ - CLASIFICĂRI - AVANTAJE - DEZAVANTAJE

(Rezumat)

Acest articol este al doilea din studiul efectuat asupra aeroglisoarelor. Prima parte a acestui studiu include descrierea aeroglisoarelor și prezentarea unei scurte istorii.

Acest articol prezintă informații referitoare la primele principii constructive ale vehiculelor cu pernă de aer, criterii de clasificare a aeroglisoarelor cât și avantajele și dezavantajele utilizării acestor tipuri de vehicule. Autorii prezintă informații mai puțin cunoscute despre primele două modele constructive, care au avut un impact major asupra dezvoltării vehiculelor cu pernă de aer și subliniază diferențele dintre acestea. Clasificarea aeroglisoarelor se realizează ținând cont de unele dintre cele mai importante criterii și include prezentarea celor mai cunoscute forme constructive de vehicule cu pernă de aer. Unele dintre cele mai importante clase de aeroglisoare, care sunt încă în serviciu activ sau care au fost utilizate în domeniul militar, sunt prezentate în format tabelar, informațiile fiind compilate din diverse surse.