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HOVERCRAFTS - AN OVERVIEW
Part I:
BASIC CONCEPTS OF ADVANCED MARINE VEHICLES - FUNDAMENTAL ELEMENTS, SHORT HISTORY, PATENTS

BY

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Abstract. Given that most of the hovercraft-related information is in a very short supply, due to the fact that most of research was carried out within military domain (that resulted in classifying information on experiments, prototypes and patents), a study related to these vehicle is carried out in a series of three articles containing general information. This study is structured in such a way that each article presents necessary information for the reader to get an ample image about this area, not very well known, at least in Romania.

This first article of the series covers the description Advanced Marine Vehicles categories and subcategories, introductory elements on two types of vehicles from the hovercraft category (constructive description, similarities and differences), a brief history comprising most important research, personalities and hovercraft companies that contributed significantly to the development of this concept.

Keywords: Landing Craft Air Cushion (LCAC); Advanced Marine Vehicle (AMV); Air Cushion Vehicle (ACV); Surface Effect Ship (SES).

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1. Introduction

Even if the concepts and operation encountered in the first prototypes of hovercrafts have been discovered long time ago, major research contributions to the area have occurred in the 20th century.

This concept has been extensively studied by the military forces of various countries in order to create stunning amphibious vehicles to operate at high speeds, to exhibit higher performance than some conventional ships, with relatively accessible production costs and with ability to carry both military equipment and troops where needed.

Thanks to these studies, the best know air cushion vehicle that is part of the hovercraft category is LCAC (Landing Craft Air Cushion) that impresses both through its constructive form and performance. The specifications of this vehicle are: weighs 182 long tons, overall dimensions of 28 x 14.7 m and the operating speed of about 74 km/h (US Navy Fact File). A representation of a constructive model for this type of vehicle is shown in Fig.1.

With respect to the general constructive form of hovercrafts, this has evolved over time, resulting in vehicles of large dimensions (especially hovercrafts used by the military forces).

An eloquent example that demonstrates the variety of both constructive form and performance of an LCAC is the Zubr class - class where the dimensions of such an air cushion vehicle would be 57 m x 25.6 m with a full loaded displacement of 555 tons (Naval Technology). A representation of this class of vehicles, currently used by the Russian army, is shown in Fig. 2.

The main purpose of this study was to gather and synthesize the most important information related to these types of vehicles. It should be noted that this study focuses more on presenting information on air cushion vehicles (ACV) and less on the presentation of surface effect ships (SES) and during the necessary documentation to prepare this study, no such structure has been encountered.

Fig. 1 – Landing Craft Air Cushion 55 (US Navy Fact File).

Fig. 2 – 782 Mordovia and 770 Yevgeny Kocheshkov air cushion landing craft (Naval Technology).

2. Basic Concepts about Advanced Marine Vehicles

Since ancient times, means of transportation played a very important role in economic development of a state. Eloquent examples of countries with an economic ascent due to developed marine transportation routes are Egypt, Greece, China and the Roman Empire (Nistor and Popa, 2014).

Along the stages in the development of civilization, various means of transport have been developed. Due to this evolution, a wide range of transport categories is currently available, such as land transportation (road, rail and underground transport), water transportation (inland water, underwater and ocean transport) and air transportation (including also space transport) (Somashekar, 2013).

This study focuses on description of hovercrafts, that fall into all three main categories, because their unique abilities.

The special class of Advanced Marine Vehicles stems from the desire to build vehicles that achieve higher operating speeds compared to conventional vehicles and ships. This class of crafts includes several types of vehicles, most of which are mainly used for maritime transport.

A detailed presentation of this class type of vehicle is shown in Fig. 3 (Ghassabzadeh and Ghassemi, 2013) where it can be seen that there are four major categories of vehicles: hovercraft, hydrofoils, monohull and multihull.

From the categories mentioned above, only one subcategory of the hovercraft class can operate on different types of surfaces such as water, earth, sand, marsh etc. These types of vehicles are known as air cushion vehicles that impress both through their constructive form and the fact that they have unmatched amphibious qualities. To better understand the capabilities that this type of vehicle can offer, in Fig. 4 are presented some functional features that make it unique compared to other types of transport (Saini *et al.*, 2016).

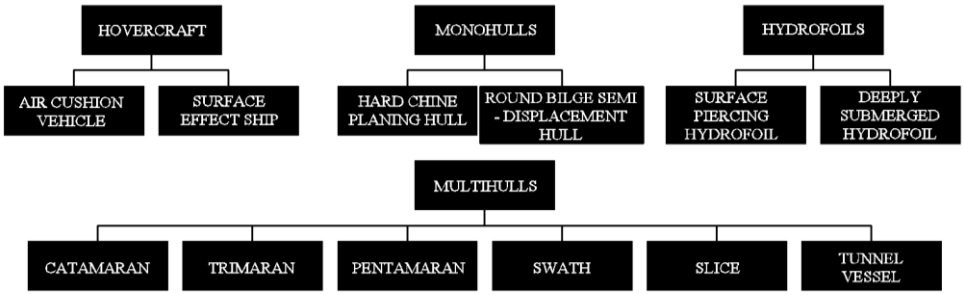


Fig. 3 − Classification of Advanced Marine Vehicles according to the hull vehicle (adapted from Ghassabzadeh and Ghassemi, 2013).

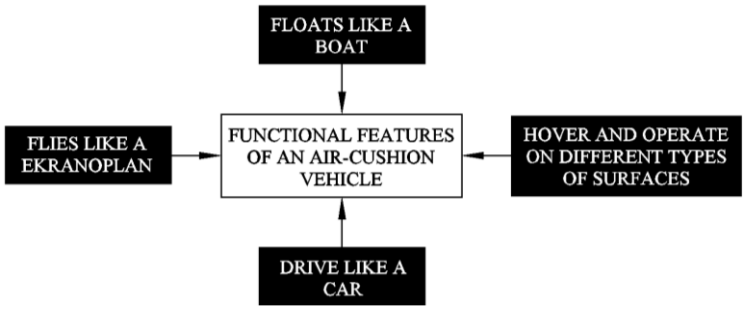


Fig. 4 − Functional features of an air-cushion vehicle.

A general analysis regarding the means of transport development would reveal that the main incentives were both the introduction of new materials with superior properties and the emergence of new components designed to increase vehicle performance. For example, increasingly efficient and lightweight power sources (high-speed diesel / gas turbine engines) and the development of new materials such as glass-reinforced plastic, aluminum alloys or titanium alloy (Yun and Bliault, 2012).

Researchers have noted that ships can develop higher navigation speeds if the structure is partly immersed in water or the structure is constructed in such way that the hull is above water when the ship is operating. To highlight these particularities, a Sustention Triangle has been designed to show for each type of vehicle from the AMV class the characteristic force raising the hull (powered lift, dynamic lift or buoyancy) (Clark *et al.*, 2004).

3. Basic Elements about Hovercraft

An analysis on the differences between the constructive forms of the hovercrafts and other types of transport vehicles would show that hovercraft construction is unique because it operates with the aid of an air cushion carried under the hull. The air cushion has different proprieties, but the most important is that it leads to a decrease in the frictional force existing between the running surface and the lower part of the flexible skirt. This concept of operation has many advantages compared to vehicles that operates on ground surfaces.

The classification in Fig. 3, shows that hovercrafts are divided into two main categories, ACV and SES, with constructive models presented in Fig. 5. There are differences related to their constructive form. Fig. 6 shows main components of air cushion vehicle, common to various constructive models. Fig. 7 (Yun and Bliault, 2012) presents main components of surface effect ship: 1 - lift fan, 2 - lift engine, 3 - propulsion engine, 4 - bow flexible seal, 5 - lift air plenum chamber, 6 - ground surface, 7 - side wall, 8 - stern flexible seal.

Fig. 5 − Hovercraft categories.

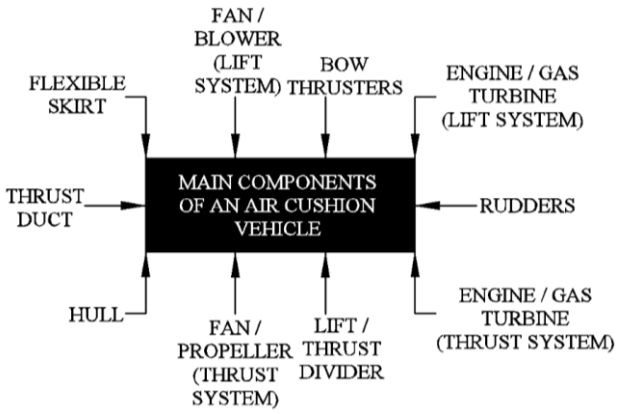
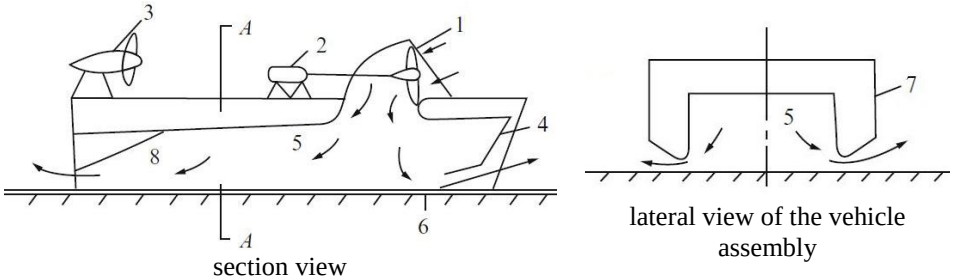


Fig. 6 − Main components of an air cushion vehicle.



section view

lateral view of the vehicle assembly

Fig. 7 − Main components of a surface effect ship.

A comparative analysis between the two vehicles (ACV and SES) was performed and similarities and differences are highlighted in Table 1.

Table 1
Similarities and Differences between ACV and SES

Similarities	Differences
• Both vehicles operate with an air cushion formed under the hull • Both vehicles have sealing elements connected by the hull • Both vehicle are running based on lift force	• SES can operate only on water / ACV can operate on different types of surfaces • SES have naval propellers used to achieve thrust force / ACV have air propellers or fans to achieve the thrust force • The basic structure of the SES consists in two side walls and two flexible elements with sealing role, while the basic structure of the ACV consists of a flexible skirt surrounding the entire periphery of the vehicle • Due to the SES constructive form, requires less lift capacity compared to ACV (AIMU - High Speed Craft) • SES offers better stability than ACV

The performance of an ACV is characterized by two parameters: power-to-weight ratio and power-to-weight-to-strength ratio. The first parameter is able to determine the distance between the running surface and the lower part of the air cushion's flexible skirt. The second parameter refers to the main features of the hull (must be made of a relatively low weight material and strong enough to withstand the entire payload) (Pragyan).

4. A Brief History about Hovercraft

The following is a chronological presentation of most important events in the hovercraft field, Table 2.

Table 2
Chronological Order of Events Related to the Development of Hovercrafts

No.	Year	Inventor / Company	Description of the event	Patent number
1.	1716	Emanuel Swedenborg	First inventor to present a concept on formation of an air cushion under the hull of a boat. Concept was similar to an overturned boat with a manual air guidance system and air inserted into the inner cavity. Proposed model was published in Daedalus Hyperboreus (Cramp, 2001; McPeake, 2004).	N/A

Table 2
Continuation

No.	Year	Inventor / Company	Description of the event	Patent number
2.	1865	William Fronde	Proposed principle of air lubrication in a letter sent to a Chief Constructor of the Royal Netherlands Navy (Herring and Fitzgerald, 2006).	N/A
3.	1876	John Ward	Proposed a constructive model with an aluminum hull with attached fans to introduce air under the hull and achieve the lift force. Wheels made contact with the running surfaces (Herring and Fitzgerald, 2006).	US PATENTS 185465 / 195860
4.	1877	John Thornycroft	Obtained a patent on a concept of a thin layer of air on the wetted surface of a ship (Yun and Bliault, 2000).	–
5.	1882	Gustaf Patrik de Laval	The Swedish inventor has obtained a patent for air lubrification around a hull ship (Yun and Bliault, 2000).	US PATENT 280913A
6.	1888	James Walker	Obtained a patent related to a boat that contains channel inside the hull through which air circulates (Herring and Fitzgerald, 2006).	US PATENT 624271
7.	1897	Andrew Culbertson	Obtained a patent on a side wall air cushion craft (Herring and Fitzgerald, 2006; Lebkowski, 2017).	US PATENT 608757
8.	1906	Schweder F.W.	Obtained a patent related to improved model presented by Gustaf Patrik de Laval (Herring and Fitzgerald, 2006).	BRITISH PATENT 4131
9.	1907	C. Joseph	Obtained a patent for a vehicle operating on the principle of air-cushion vehicles (Herring and Fitzgerald, 2006).	US PATENT 989834
10.	1914	James Porter	British inventor, obtained a patent for a model similar to the annular duct (Herring and Fitzgerald, 2006).	BRITISH PATENT 975
11.	1916	Herr Dagobert Muller von Thomamhul	Built for the Austrian Navy a boat with air blowers to introduce air between the sidewalls and was used as a torpedo boat (Mantle, 2015).	–
12.	1921	M.A. Gambin	French inventor, submitted a patent for a sidewall type air cushion vehicle (Herring and Fitzgerald, 2006).	BRITISH PATENT APPLICATION 188648

Table 2
Continuation

No.	Year	Inventor / Company	Description of the event	Patent number
13.	1925	V.F. Casey	Obtained a patent for an air-cushion vehicle which recirculates the air used (Herring and Fitzgerald, 2006; Amyot, 1989).	US PATENT 1621625
14.	1927	K. Tsiolkovsky	Published a fundamental paper on theoretical methods of calculation for air-cushion vehicles (Tsiolkovsky, 1927; Kumbhalkar *et al*., 2017)	N/A
15.	mid 1930's	V. Levkov	Worked on a concept called hovertank (similar to air cushion vehicle) but because of the outbreak of the Second World War, this project was abandoned (Lloyd *et al*., 2015).	–
16.	1935	T.J. Kaario	Engineer at Valmet Corporation, built and experimented several vehicles based on ground effect (Herring and Fitzgerald, 2006; Mantle, 2015).	FINNISH PATENTS 18630/26122
17.	1953	J.C. Fletcher	Built a vehicle similar to today's ACV, GlideMobile, but project was classified. Invented on August 3, 1953 and tested in New Jersey on December 5, 1959 (Barth, 2013; Aviation Hall of Fame).	–
18.	1956	J. Bertin	Built the first train running on the base of the air cushion. A constructive model manage to achieve in 1969 an impressive speed of 422 km/h (Bejan and Bălan, 2012; Meunier, 2002).	–
19.	1959	W.R. Bertelsen	Built a vehicle that operated with an air cushion - Aeromobile (A - 35). Prototype featured a twin - cylinder Righer drone engine with 35 HP and second model, Aeromobile - 72, had a much stronger engine (Mantle, 2015).	–
20.	1959	Saunders Roe Company	The first launch of a 3.4 tons ACV - SR.N1. The total power output of the engine was 320 kW, 70% for lift force and 30% for thrust force. On July 25, crosses English Channel (between Dover and Calais). (Bejan and Bălan, 2012; Yun and Bliault., 2000; Yun and Bliault, 2012).	N/A

Table 2
Continuation

No.	Year	Inventor / Company	Description of the event	Patent number
21.	1959	–	The Chinese built an ACV - Craft 33 tested in July at Lu Shun. It had no peripheral jet, but had a plenum chamber (Yun and Bliault, 2000).	N/A
22.	early 1960s	Saunders Roe Company	Designed ACVs: SR.N2 and SR.N3 to be used as patrol vehicles and ferry-boats (Wikipedia - SR.N2; Wikipedia - SR.N3).	N/A
23.	1961	N. Latimer	Patent on flexible skirt (on invention made in 1958) sold to Saunders – Roe (Yun and Bliault, 2000).	N/A
24.	1962	Vickers Armstrong	Vickers VA-3 was the first ACV used for commercial purposes. The official first run between Wirral and North Wales on July 20 (BPI India, 2015).	N/A
25.	1963 - 1964	–	SR.N2 runs regularly between Eastney and Ryde carrying 30.000 people (Wikipedia - SR.N2).	N/A
26.	1964	–	First hovercrafts competition in Canberra - Australia. There were 11 amateurs who came with prototypes (Tanswell, 1964).	N/A
27.	1965	–	Hovermarine Company Limited was established to develop new SES with superior characteristics (Yun and Bliault, 2000).	N/A
28.	1968	Hovermarine Limited	Launched HM-2, its first SES, followed by improvement of this prototype (HM-2 MK2, HM-2 MK3, HM-221) (Yun and Bliault, 2000).	N/A
29.	1970 - 1983	–	The ACV BH.7 MK.2 in operation and used for many applications such as anti-submarine combat, mine countermeasure etc. (Wikipedia - BH.7).	N/A
30.	1974	–	Due to fuel prices, this concept has stalled because these vehicles were no longer economically viable (Yun and Bliault, 2000).	N/A
31.	1990	–	The concept of ACV revives the interest of general public.	N/A
32.	present	–	Numerous companies produce ACVs for various applications. Currently, the ACV types vary from vehicles that can transport 1 to 2 people to vehicle that can carry several tons.	N/A

5. Conclusions

The detailed information presented in this paper, demonstrates that hovercrafts have always been a special concern for many researchers as well as for ordinary people. The constructive features of the two types of vehicles that are part of the hovercraft category are unmatched in any type of transport, making these vehicles unique in the world.

Many of the researchers are mentioned in Table 2, but because these types of vehicles have been extensively studies by the military domain, some of them are missing, the information being classified. The most important person in this area is considered to be Christopher Cockerell, an engineer who has made real contributions to creating ACVs.

The continuing need for development of the means of transport and the need to conceive vessels / vehicle that achieve high speeds of operation, have led to the emergence of Advance Marine Vehicles, which may be considered as engineering masterpieces.

Issues related to both high-speed handling and stability of air cushion vehicle - issues that are being investigated today have led to stagnation of this concept to be deployed on a large scale. Also, the low interest in this area is due to the fact that research would involve quite high costs, equipment, specialized personnel and materials.

This area remains open, so that every researcher has the possibility of making a major impact can lead to widespread implementation of these types of vehicles by providing cases studies.

REFERENCES

Amyot J.R., *Hovercraft Technology, Economics and Applications*, Elsevier Science Publishers B.V., 1989.

Barth L.J., *A History of Inventing in New Jersey: From Thomas Edison to the Ice Cream Cone*, The History Press, 2013.

Bejan M., Bălan I., *Vehicule cu pernă de aer*, A XII-a Conferință Națională multidisciplinară - cu participare internațională, "Profesorul Dorin PAVEL - fondatorul hidroenergeticii românești" (2012).

BPI India, *Children's Illustrated Treasury of Knowledge: Transportation*, S. Chand (G/L) & Company Ltd, 2015.

Clark D.J., Ellsworth W.M., Meyer J.R., *The Quest for Speed at Sea*, Naval Surface Center, Carderock Division, Technical Digest (2004).

Cramp L.G., *The A.T. Factor: Piece for a Jigsaw III*, Adventures Unlimited Press, 2001.

Ghassabzadeh M., Ghassemi H., *An Innovative Method for Parametric Design of Planing Tunnel Vessel Hull Form*, Ocean Engineering, **60**, 14-27 (2013).

Herring S., Fitzgerald C., *History of the Hovercraft*, Neoteric Hovercraft Inc., 2006 https://archive.neoterichovercraft.com/general_info/historyof.htm (accessed on 14.05.2018).

Kumbhalkar V., Khodke N., Khaparkar A., *Study of Aerodynamics*, International Research Journal of Engineering and Technology, **4**, 1 (2017).

Lebkowski A., *Researching the Impact of Electric Boat Hull Aeration Energy Consumption*, Scientific Journal of Gdynia Maritime University, **98**, 148-156 (2017).

Lloyd J., Mitchinson J., Harkin J., Murray A.H., *QI: The Third Book of General Ignorance*, Faber & Faber Ltd., 2015.

Mantle P.J., *High - Speed Marine Craft - One Hundred Knots at Sea*, Cambridge University Press, New York, 2015.

McPeake M., *A Research Paper on the History of the Hovercraft*, Tech High Senior Engineering, 2004, http://hovertron.tripod.com/images/mpaper.pdf (accessed on 14.05.2018).

Meunier J., *On the Fast Track: French Railway Modernization and the Origins of the TGV, 1944 - 1983*, Praeger Publishers, 2002.

Nistor F., Popa C., *The Role of Transport in Economic Development*, "Mircea cel Bătrân" Naval Academy Scientific Bulletin, **XVII**, 2 (2014).

Saini A., Gupta A., Singh B.P., Kumar B., Soni D., Gautam K., *A Hovercraft*, International Journal of Engineering and Management Research, **6**, 2 (2016).

Somashekar N., *Problems of working Women in Transport Industry: A Case Study of BMTC Women Conductors*, PhD Thesis, Bangalore University, Chapter 4, 2013, http://hdl.handle.net/10603/69376.

Tanswell N., *World's First Hovercraft Races*, FLIGHT International Supplement – Air Cushion Vehicles, 23 April 1964, 49-52 (1964).

Tsiolkovsky K.E., *Resistance of Air and Fast Train* (in Russian), 1st Guest, The State Forestry Service, 1927, https://www.prlib.ru/item/450905.

Yun L., Bliault A., *High Performance Marine Vessels*, Springer New York Dordrecht Heidelberg London, 2012.

Yun L., Bliault A., *Theory and Design of Air Cushion Craft*, Arnold - A Member of the Hodder Headline Group, Great Britain, 2000.

*** American Institute of Marine Underwriters Technical Services Committee, *High Speed Craft Report*, http://www.aimuedu.org/aimupapers/hsc.pdf (accessed on 16.05.2018).

*** Aviation Hall of Fame, *Teterboro, NJ - GlideMobile Hovercraft*, http://www.williammaloney.com/Aviation/AviationHallOfFameTeterboroNJ/GlidemobileHovercraft/index.htm (accessed on 16.05.2018).

*** Naval Technology – Zubr Class LCAC (Pomornik), https://www.naval-technology.com/projects/zubr/ (accessed on 16.05.2018).

*** Pragyan, *Basic Hovercraft Theory*, 3rd Dimension Aeromodelling Club Trichy, https://www.pragyan.org/15/home/events/core_engineering/hover_one/resources/Theory%20of%20Hovercraft.pdf (accessed on 16.05.2018).

*** US Navy Fact File, Landing Craft Air Cushion, *Landing Craft Air Cushion* http://www.navy.mil/navydata/fact_display.asp?cid=4200&tid=1500&ct=4, (accessed on 16.05.2018).

*** Wikipedia - BH.7, *British Hovercraft Corporation BH.7*, https://en.wikipedia.org/wiki/British_Hovercraft_Corporation_BH.7 (accessed on 16.05.2018).

⁂ Wikipedia - SR.N2, *SR.N2*, https://en.wikipedia.org/wiki/SR.N2 (accessed on 16.05.2018)
⁂ Wikipedia - SR.N3, *SR.N3*, https://en.wikipedia.org/wiki/SR.N3 (accessed on 16.05.2018).

AEROGLISOARE - O PREZENTARE GENERALĂ
PARTEA I:
CONCEPTE DE BAZĂ PRIVIND VEHICULELE MARINE AVANSATE - ELEMENTE FUNDAMENTALE, SCURT ISTORIC, BREVETE DE INVENȚIE

(Rezumat)

Având în vedere faptul că majoritatea informațiilor legate de aeroglisoare se găsesc într-un număr foarte mic, datorită faptului că cea mai mare parte a cercetării a fost realizată de către domeniul militar (acest lucru a dus la clasificarea informațiilor privind experimentele, prototipurile și brevetele de invenție), un studiu privind aceste tipuri de vehicule este realizat într-o serie de trei articole, care conțin informații generale. Despre acest studiu se poate spune că este structurat în așa manieră încât fiecare articol să prezinte informații necesare astfel încât cititorul să aibă o imagine de ansamblu despre acest domeniu foarte puțin cunoscut, mai ales în România. Acest prim articol al seriei cuprinde descrierea categoriilor și a subcategoriilor privind Vehiculele Marine Avansate, noțiuni introductive despre cele două tipuri de vehicule din categoria aeroglisoarelor (descriere constructivă, asemănări și diferențe), o scurtă istorie cuprinzând cele mai importante cercetări, personalități și companii producătoare de aeroglisoare, care au contribuit semnificativ la dezvoltarea acestui tip de concept.