BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 66 (70), Numărul 3, 2020
Secţia
CONSTRUCŢII DE MAŞINI

HOVERCRAFTS - AN OVERVIEW
Part III:
MAIN COMPONENTS OF AIR CUSHION VEHICLES

BY

MIHAI-SILVIU PAVĂL[1,*], ARISTOTEL POPESCU[2] and DĂNUȚ ZAHARIEA[1]

“Gheorghe Asachi” Technical University of Iaşi,
[1]Faculty of Machine Manufacturing and Industrial Management
[2]Faculty of Mechanical Engineering

Received: July 27, 2020
Accepted for publication: September 30, 2020

Abstract. The main purpose of this paper is to present the construction features of air cushion vehicles. It reports on aspects about the main components: hull (constructive characteristics constrains, exterior constructive forms, internal configurations, transfer holes shapes, materials), flexible skirt (types, shapes and materials) and parts of both lift and thrust system. The influence of geometric shape of the hull base and flexible skirt on vehicle performance is also presented, as well as a discussion on most frequently encountered technical solutions and advantages offered. The authors contribution relies in structuring the information and solutions found in literature into comparative images and diagrams, and to present a clear image on state-of-the-art of the constructive characteristics of air cushion vehicles.

Keywords: hull; flexible skirt; rudders; lift system; thrust system.

1. Introduction

This is the concluding article in a series of three, published with main purpose of presenting the general aspects regarding the hovercraft, with emphasis on the air cushion vehicle category. Given that the first two articles

[*]Corresponding author; *e-mail*: pavalmihaisilviu@gmail.com

focused on the basic concepts of advanced marine vehicles, fundamental elements, basic constructive principles, classifications, advantages and disadvantages of using these vehicles, the main purpose of this study is the presentation of the constructive details of air cushion vehicles.

Considering that the whole concept of this type of vehicle has been developed over the years, at this moment various construction models impress with various technical features such as: configuration, number of passengers, tank capacity, construction dimensions, fuel consumption and many other.

Not taking into account the electrical system, electronic equipment, some elements of the steering system and small components, Fig. 1 shows the main components found in all types of air cushion vehicles. Each component presented is part of one of the three systems found in air cushion vehicles, namely: lift system, thrust system and steering system.

2. Main Components - Hull

Being considered to be one of the most important components of an air cushion vehicle, the hull has to be very high in strength and to have a relatively low weight to contribute to the high performance that a vehicle needs to perform. This is due to the fact that most of the equipment, with the exception of the flexible skirt, is mounted on it.

Given the struggle to improve the performance of air cushion vehicles, over time there was a continuous evolution in the hull construction.

The most important constructive aspects regarding this component are the following: the outer and inner shape of the hull, the shape of the cushion feed orifice also known as transfer holes, the constructive form of the hull base, the main materials used in the construction of this component and the main characteristics that it must satisfy.

Regarding the outer shape, this may have several forms: circular, rectangular with chamfered corners, circular in the front and rounded back corners, rectangular, rectangular with rounded corners and triangular with two rounded sides (Hovery Hovercraft; All Surface Vehicles; Air Rider Hovercraft; Universal Hovercraft; Griffon Hoverwork).

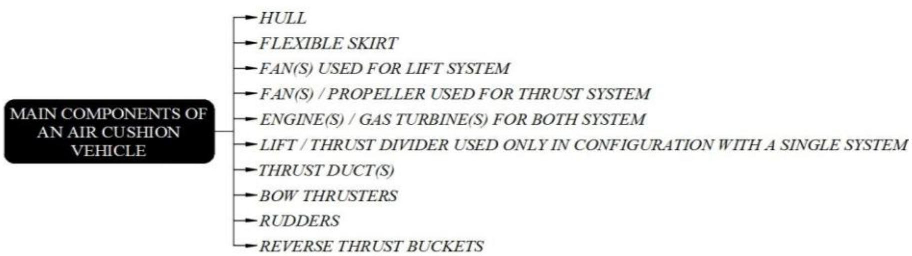


Fig. 1 − Main components that can be found in all types of air cushion vehicle configurations.

Regarding the inner shape of the hull, this is closely related to the development of flexible skirt. Therefore, in Fig. 2 are presented the main internal configurations specific to the lift system, where: 1 – air source, 2 – hull, 3 – buoyancy tank, 4 – flexible skirt, 4' – skirt bag, 5 – skirt segments that are known as fingers and 6 – running surface.

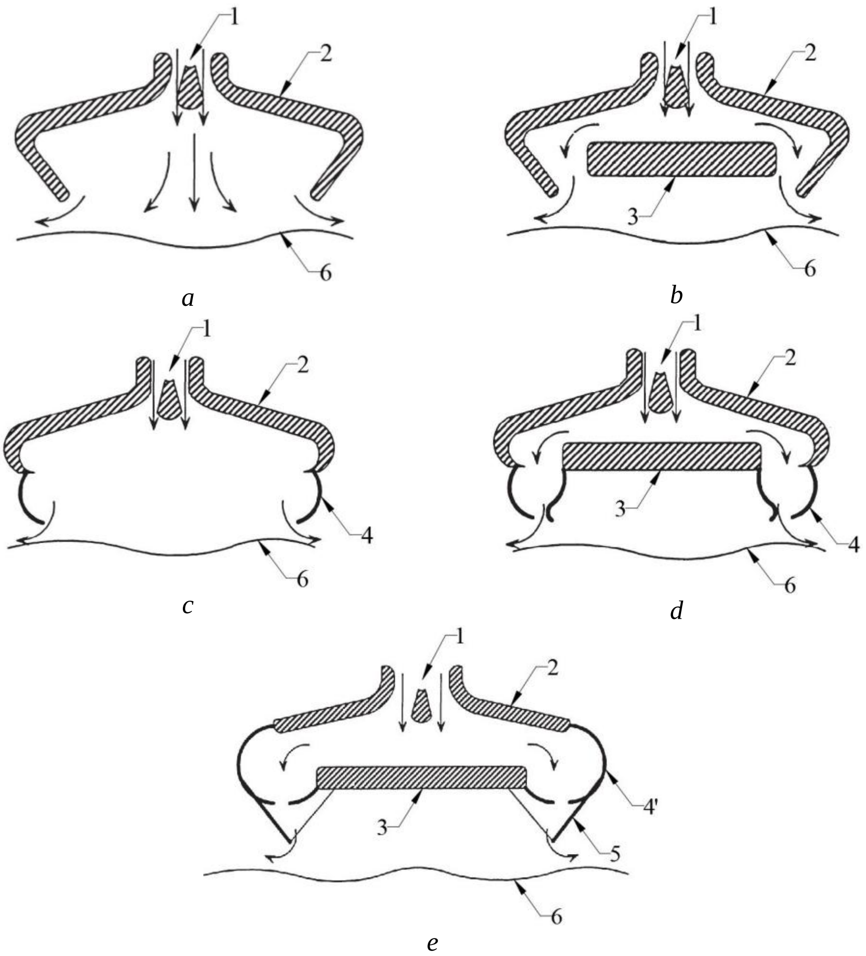


Fig. 2 – The evolution of the inner shape of the hull as well as the flexible skirt over time: *a* – simple plenum, *b* – simple peripheral jet, *c* – skirted plenum, *d* – skirted peripheral jet and *e* – modified plenum (skirted) (adapted from Jung, 2003).

The hull component also includes cushion feed orifices, which are also known as transfer holes and the main role is to allow air to exit the hull and direct it under a certain trajectory in the flexible skirt. Regarding the main shapes of cushion feed orifices, these can be round or elongated and are shown in Fig. 3.

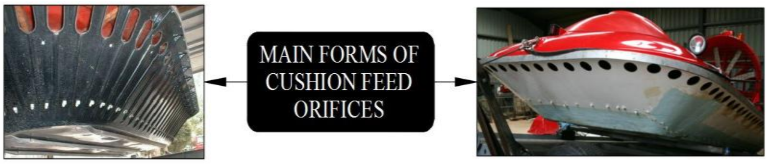
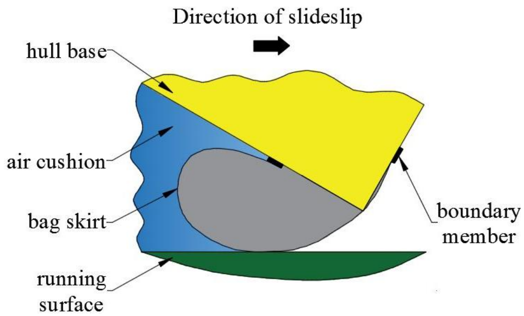


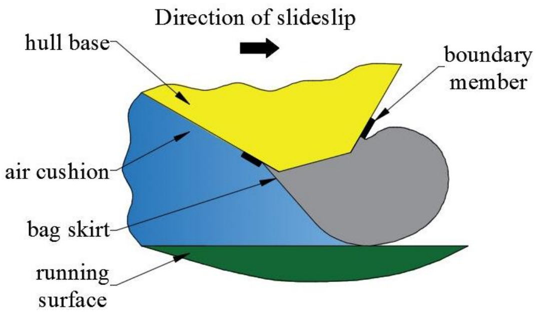
Fig. 3 – Constructive forms regarding cushion feed orifices
(Reynolds-Towers, SpeedJunky).

An important aspect related to hull is the shape of the base. As can be seen in Fig. 4, where two separate cases are presented, it must have a tilt angle between 25° and 35° to prevent the skirt from entering beneath the hull when the vehicle slides (Knapp, 2011).

The most used types of materials in the construction of this component of the air cushion vehicle are shown in Fig. 5 (Yun and Bliault, 2000; Border Security Products; Viper Hovercraft; Lone Star Hovercraft; AirLift Hovercraft; Hoverstream LLC). Figure 6 presents the main characteristics that hull must fulfill in order for the vehicle to be able to operate at optimal parameters.



a



b

Fig. 4 – The influence of the angle of the hull base when vehicle slides: *a* – hull base with angle at 90° and *b* – hull base with inclined angle (adapted from Knapp, 2011).

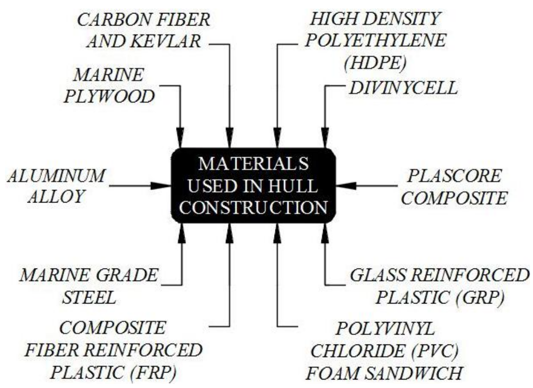


Fig. 5 – Main materials used in hull construction.

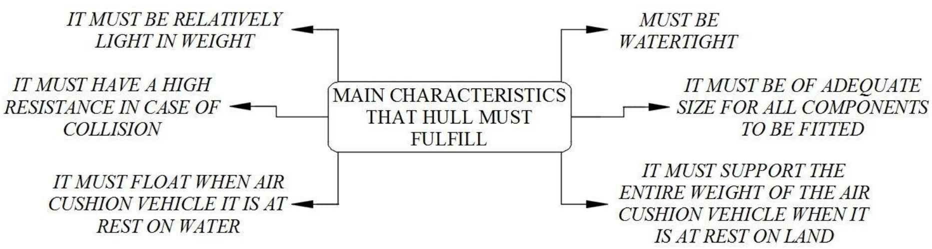


Fig. 6 – Main characteristics that hull must fulfill.

3. Main Components - Flexible Skirt

About flexible skirt it can be said that this is the component that makes air cushion vehicle unique compared to other means of transport. It is also the most sensitive of all components because it makes the connection between running surface and hull and the main feature is that it retains the amount of air given by the fan to form the air cushion necessary for the vehicle to rise from the ground and be able to operate on any type of running surfaces.

The first air cushion vehicle models did not have a flexible skirt, which in this case the air source had to provide a large flow of air to achieve the air cushion under the hull and to compensate for losses from the vehicle's periphery. Therefore, these models could not operate on any type of running surfaces and also had low performance compared to models that have a flexible skirt.

An important aspect regarding the evolution of this component is the invention of the segmented skirt by Dennis Bliss in 1962 (Yun and Bliault, 2000). This type of skirt is currently used in the construction of these types of vehicles because it has higher characteristics compared to other models of flexible skirts.

Over time, there have been several concepts of skirts, differentiated by their constructive form. The most significant models created for air cushion vehicles are presented in Fig. 7. It should also be mentioned that for some types of flexible skirts a certain type of material corresponds, due to the characteristics of each material.

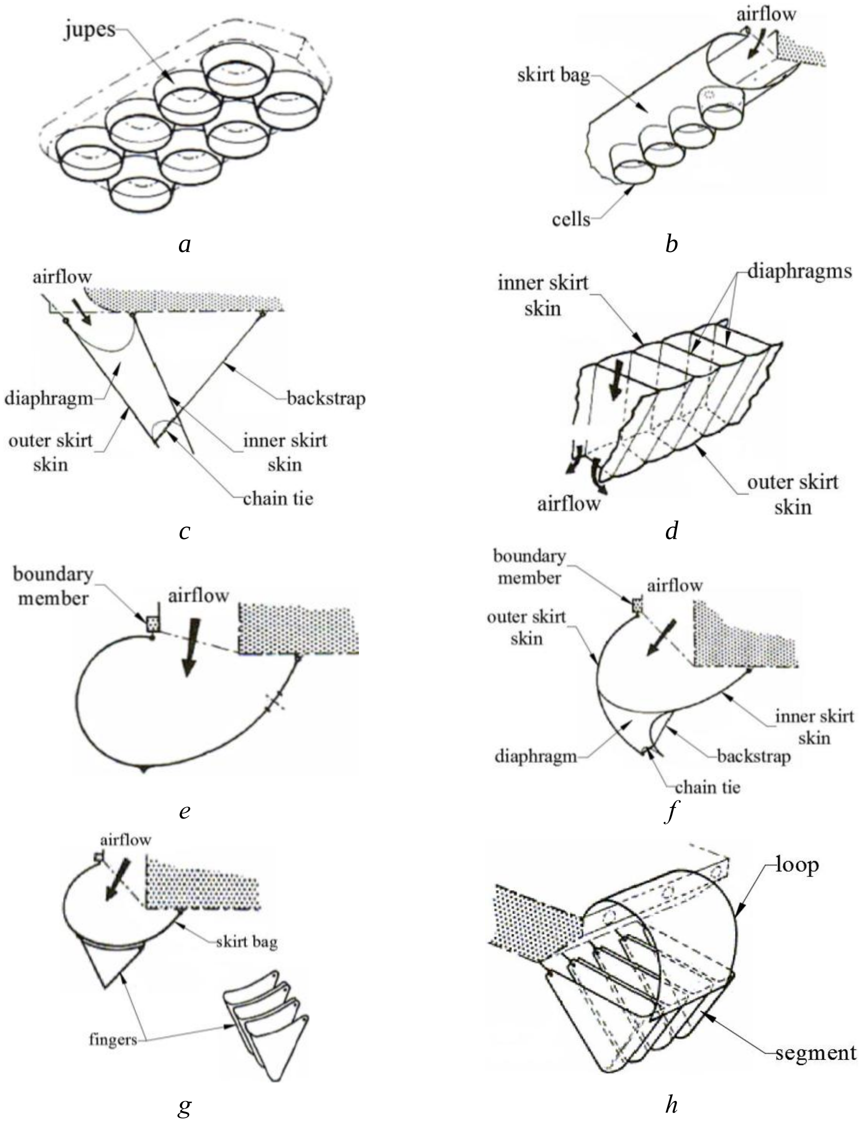


Fig. 7 – The main flexible skirts encountered on air cushion vehicles over time: *a* – Bertin skirt, *b* – Peri-cell skirt, *c* – Trunked skirt, *d* – Convoluted skirt, *e* – Loop / bag skirt, *f* – Jetted skirt, *g* – Bag and finger skirt, *h* – Segmented skirt (adapted from Carrillo Vilchis *et al.*, 2006).

The main materials used in the production of flexible skirt are shown in Fig. 8 (Shrirao *et al.*, 2016; British Hovercraft Company; Hoverhawk Corporation; Hovertechnics; Hovercraft.org) and in Fig. 9 are presented the main features that a flexible skirt has to fulfil in order to be useful for an air cushion vehicle (Jaiswal *et al.*, 2014).

When choosing a material for any types of skirt, it is first of all taken into account that the selected materials must have two essential proprieties: to be tough and resistant to wear. The main advantages that the flexible skirt can offer are shown in Fig. 10 (Yun and Bliault, 2000).

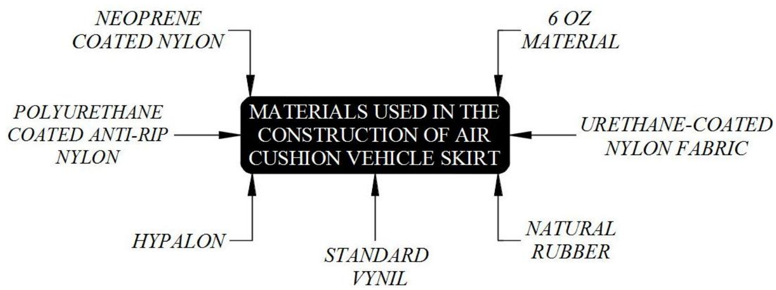


Fig. 8 – Main materials used in the production of flexible skirts.

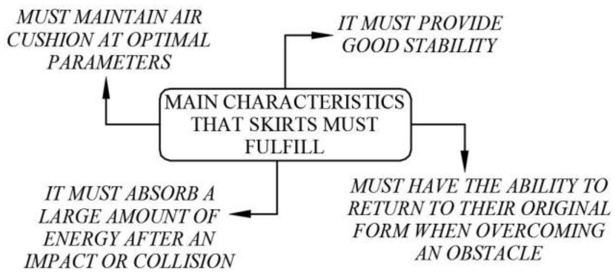


Fig. 9 – Main characteristics that skirt must fulfill.

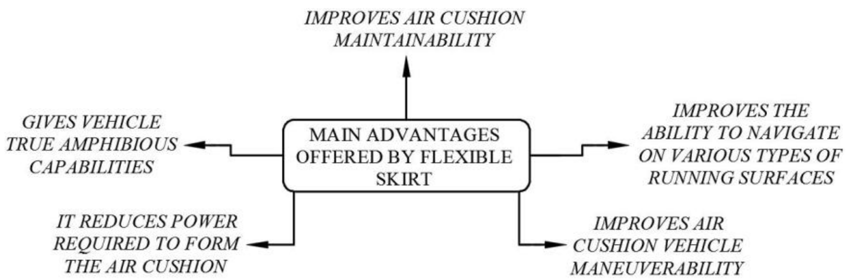


Fig. 10 – Main advantages offered by flexible skirt.

4. Main Components – Types of Lifting Fans / Thrust Fans and Types of Engines / Gas Turbines

Reporting only to the lift system, Fig. 11 (Amyot, 1989) shows the fans that have been used / are currently used in the construction of these types of vehicles. Considering the axial fan, it is used both in the air cushion vehicle with a single system (axial fan achieves both lift and thrust force) and in the version with two systems where the axial fan performs only the necessary lift force. Regarding large air cushion vehicle, centrifugal fans are preferred to be used to achieve lift force to the detriment of axial fans.

On the other hand, the most used components over time to achieve thrust force are represented by free air propellers, ducted air propellers or ducted fans and are shown in Fig. 12 (Pavăl and Popescu, 2018; Skycraft Propulsion Systems; James' Hovercraft Site).

In the construction of the first large models of air cushion vehicle, and this includes the models SR.N2, SR.N3, SR.N4, SR.N5 and SR.N6, free air propellers were used to obtain thrust force required. The main disadvantages in the use of these components were the noise emitted by these propellers which caused discomfort to both crew and passengers.

Regarding the elements that drive these fans or propellers, various components have been used over time. In the first medium and large air cushion vehicle models, gas turbines were used. For example, SR.N1 was equipped with 1 x B.S.E. Viper 5; SR.N2 with 4 x B.S.E. Nimbus 1000 Series, V.A. 3 with 4 x B.S.E. Turmo 603 Series; SR.N3 with 4 x R.R. Marine Gnome 1050; SR.N4 with 4 x R.R. Marine Proteus 15M/529; SR.N5 and SR.N6 with 1 x R.R. Marine Gnome 1051 each; BH-7 with 1 x R.R. Marine Proteus 15M/541) (Woodward, 1968). Currently, the most engines in air cushion vehicles are those on gasoline or diesel with 2-stroke or 4-stroke.

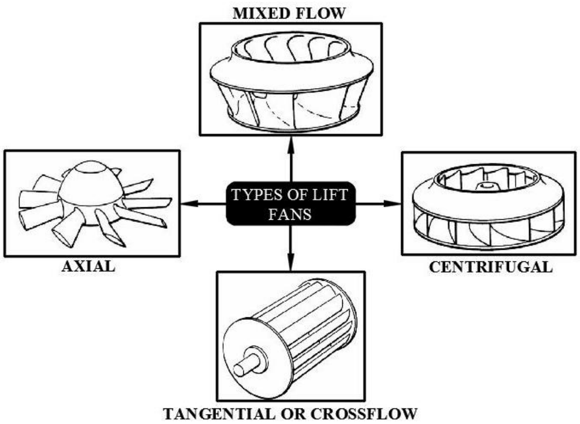


Fig. 11 – Fans used to achieve the lift force.

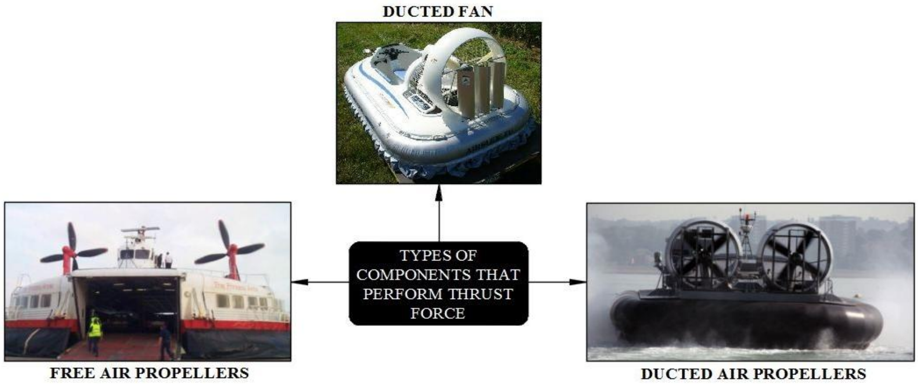


Fig. 12 – Types of components that perform thrust force.

5. Main Components - Thrust Duct, Rudders, Reverse Thrust Buckets, Bow Thrusters and Lift / Thrust Divider

Thrust duct is part of the thrust system and has two important uses, *i.e.*, protects the axial fan or propellers and regulates the airflow. Regarding the location of this component, it can be found at the rear of the vehicle.

Rudders are aerodynamic profile plates that are located at the outlet of thrust duct and its main role is that with these components, the air cushion vehicle can be operated in the proposed direction. Figure 13 shows how these rudders rotate and the effects generated on the trajectory when vehicle operates on different running surfaces (blue arrows represent the direction of forward or rotation of the vehicle, black arrows represent the rudders orientation and red arrows represent the left or right rotation of these elements).

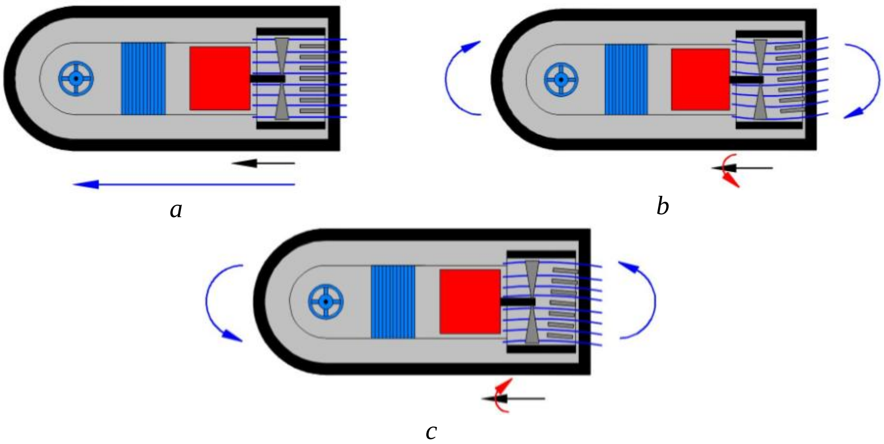


Fig. 13 – Influence of rudders orientation on air cushion vehicle trajectory (adapted from DiscoverHover).

As can be seen in the previous figure, blue lines represent streamlines coming out of the axial fan or propellers. In case A - rudders are arranged horizontally making it possible for the vehicle to operate in straight line, in case B - rudders are rotated to left which leads to the rotation of air cushion vehicle to right and case C - rudders are rotated to right which leads to the rotation of air cushion vehicle to left.

Rudders can be classified according to two criteria: according to the number of elements and according to their constructive positioning. Regarding the first criterion, air cushion vehicle has between 1 and 5 rudders on each thrust duct and regarding the second criterion, most of air cushion vehicle have rudders arranged in a vertical positioning but some models can be found that have rudders positioned under a certain angle or even positioned in a V shape (Hovertravel; ABS Hovercraft Ltd.).

Bow thrusters are components found in large air cushion vehicles and play an important role in handling these types of vehicles. These components are driven by an electric motor and direct the air flow coming from lift system (Amyot, 1989).

Reverse thrust buckets components are found in normal size air cushion vehicle that are used as a braking system (Geico Multitecnologia).

The lift / thrust divider is a component found only on selected models of air cushion vehicle, that achieves the two forces (lift and thrust) necessary for proper functioning with a single system. It divides the airflow in such a way that a certain percentage of the total is used for the lift system, while the rest is used for the thrust system (Pavăl and Popescu, 2018).

6. Conclusions

This article presents the most important components used in air cushion vehicles construction and their design evolution in time.

In air cushion vehicle prototype design, consideration should be given to: weight and material of the hull, weight center of each component, type and material of skirt, most frequent meteorological conditions the vehicle will be subjected to, type of fan / propeller used for both lift and thrust systems, aerodynamic shape of the rudders etc. An uninspired choice of one of these factors can significantly influence the performance of air cushion vehicle.

The main problems that may arise in concept design are stability and maneuverability. Another important issue considered in design is environmental impact, which cannot be said of the other means of transport that are used today.

As a final conclusion, this study conducted in three papers tried to incorporate fundamental information on the entire concept of air cushion vehicle. Currently, there is an ongoing effort in research and development of this concept and maybe in a few years we will be able to manufacture and use these types of vehicles on a large scale.

REFERENCES

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

Carrillo Vilchis O.A., King Lucio P.G., Vargas Contreras M.A., *Diseño y construcción de un vehículo de colchón de aire*, Bachelor Thesis, National Polytechnic Institute of Mexico, 2006.

Jaiswal R., Bhardwaj R., Anant R., Sen P.K., Bohidar S.H., *A Study about HOVERCRAFT*, International Journal for Scientific Research & Development, **2**, 344 – 347 (2014).

Jung T.C., *Design of Air Cushion Vehicles Using Artificial Intelligence: Expert System and Genetic Algorithm*, Master Thesis, Ryerson University, 2003.

Knapp K., *Hovercraft: lift System and Steering*, Bachelor Thesis, University of Cincinnati, 2011.

Pavăl M.S., Popescu A., *Hovercrafts – An Overview. Part II: Basic Construction Principles, Classification, Advantages, Disadvantages*, Bul. Inst. Polit. Iaşi, **64**, 51-61 (2018).

Shrirao R.R., Kale S.P., Rakhde D.K., Khot A.S., *Design & Fabrication of ACV*, International Journal of Emerging Trends in Science and Technology, **3**, 3995 - 4015 (2016).

Woodward M.L., *British Experience with Propulsion Machinery for Air Cushion Vehicles*, ASME, 1968.

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

*** ABS Hovercraft Ltd., *Transmission system*, http://www.abs-hovercraft.com/donar-hovercraft/innovative-transmission-system/ (accessed on 13.06.2020).

*** Air Rider Hovercraft, *Products*, https://airriderhovercraft.com/products/ (accessed on 08.06.2020).

*** AirLift Hovercraft, *Comparisons of Hulls*, https://airlifthovercraft.com/hovercraft-information/comparisons-of-hulls/ (accessed on 11.06.2020).

*** All Surface Vehicles, *Products*, http://www.asv-aust.com/galleries/e2_range1.htm (accessed on 08.06.2020).

*** Border Security Products, *Technology*, https://bordersecurityproducts.com/about-hov-pod/advanced-hovercraft-technology/ (accessed on 11.06.2020).

*** British Hovercraft Company, *Marlin*, https://britishhovercraft.com/marlin/ (accessed on 12.06.2020).

*** DiscoverHover, *How a Hovercraft Turns*, http://www.discoverhover.org/infoinstructors/newguides/guide13-turning.html (accessed on 13.06.2020).

*** Geico Multitecnologia, *Hovercraft HTI*, https://geico.ind.br/hovercraft-learnmore (accessed on 19.06.2020).

*** Griffon Hoverwork, *995ED*, https://www.griffonhoverwork.com/products/hovercraft/995ed-hovercraft (accessed on 08.06.2020).

*** Hovercraft.org, *Hov Pod SPX TCC 65HP*, http://www.hovercraft.org/products/hov-pod-spx-tcc-65hp/ (accessed on 12.06.2020).

*** Hoverhawk Corporation, *Hovercraft Skirt Fabric and Material*, https://hoverhawk.com/hovercraftskirtfabric.html (accessed on 12.06.2020).

*** Hoverstream LLC, *The Marlin XL*, https://www.hoverstream.com/hovercraft/marlin-xl/, (accessed on 11.06.2020).
*** Hovertechnics, *Hoverjet GT Features and Options*, http://www.hovertechnics.com/Recreational%20Light%20Hovercraft/rec-hoverjetgt.php (accessed on 12.06.2020).
*** Hovertravel, *Book Now*, https://www.hovertravel.co.uk/ (accessed on 13.06.2020).
*** Hovery Hovercraft, *Products*, http://www.hovery.com/index.php/en/productos-en (accessed on 08.06.2020).
*** James' Hovercraft Site, *SRN4 Systems Tour*, http://www.jameshovercraft.co.uk/includes/gallery.php?galName=g_n4tour&imageNo=1 (accessed on 12.06.2020).
*** Lone Star Hovercraft, *Titan 12*, https://lonestarhovercraft.com/titan-12/ (accessed on 11.06.2020).
*** Reynolds-Towers, *Osprey skirt*, http://reynolds-towers.com/?page_id=2424 (accessed on 11.06.2020).
*** Skycraft Propulsion Systems, *Hovercraft*, https://skycraftpropellers.com/hovercraft (accessed on 12.06.2020).
*** Speedjunky, *Scat Hovercraft Information*, http://www.speedjunky.net/html/index6.htm (accessed on 11.06.2020).
*** Universal Hovercraft, *Home*, https://www.hovercraft.com/content/ (accessed on 08.06.2020).
*** Viper Hovercraft, *Viper Cruiser Plans and Kits*, http://www.viperhovercraft.com.au/vipercruiserhovercraftplankits.htm (accessed on 11.06.2020).

AEROGLISOARE - O PREZENTARE GENERALĂ
PARTEA a III-a:
PRINCIPALELE COMPONENTE ALE VEHICULELOR CU PERNĂ DE AER

(Rezumat)

Scopul principal al acestei lucrări este de a prezenta particularitățile constructive ale vehiculelor cu pernă de aer. Se prezintă aspecte legate de principalele componente: structură (limitări ale caracteristicilor constructive, forme constructive exterioare, configurații interne, forma orificiilor de transfer, materiale), fusta flexibilă (tipuri, forme și materiale) și părți din ambele sisteme de sustentație și propulsie. Este prezentată, de asemenea influența formei geometrice a bazei structurii și a fustei flexibile asupra performanței vehiculului, precum și o discuție cu privire la cele mai frecvente soluții tehnice întâlnite și avantajele oferite de acestea. Contribuția autorilor se bazează pe structurarea informațiilor și soluțiilor găsite în literatură în imagini comparative și diagrame, și în prezentarea unei imagini clare de ultimă oră a caracteristicilor constructive ale vehiculelor cu pernă de aer.