INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

TO STUDY AND FABRICATION OF AIR CUSHION VEHICLE

Amit Tiwari *[1]
*[1] M. Tech (Production Engineering), Scholar, Pacific University Udaipur Rajasthan, INDIA
*Correspondence Author: amittiwari992@gmail.com

Abstract:
An Air cushion vehicle is a vehicle that flies like a plane but can float like a boat, can drive like a car but will traverse ditches and gullies as it is a flat terrain. An air cushion vehicle also sometimes called an air cushion vehicle because it can hover over or move across land or water surfaces while being held off from the surfaces by a cushion of air. A Hovercraft can travel over all types of surfaces including grass, mud, muskeg, sand, quicksand, water and ice .Hovercraft prefer gentle terrain although they are capable of climbing slopes up to 20%, depending upon surface characteristics. Modern Hovercrafts are used for many applications where people and equipment need to travel at speed over water but be able load and unload on land. For example they are used as passenger or freight carriers, as recreational machines and even use as warships. Hovercrafts are very exciting to fly and feeling of effortlessly traveling from land to water and back again is unique.

Keywords:
Working Principle, Methodology, Calculation and Future Scope.

Cite This Article: Amit Tiwari, "To Study and Fabrication of Air Cushion Vehicle." *International Journal of Research – Granthaalayah,* Vol. 3, No. 3(2015): 70-84.

1. INTRODUCTION

A hovercraft, also known as an air-cushion vehicle or ACV, is a craft capable of traveling over land, water, mud or ice and other surfaces both at speed and when stationary. Hovercrafts are hybrid vessels operated by a pilot as an aircraft rather than a captain as a marine vessel. Hovercraft use blowers to produce a large volume of air below the hull that is slightly above atmospheric pressure. The pressure difference between the higher pressure air below the hull and lower pressure ambient air above it produces lift, which causes the hull to float above the running surface. For stability reasons, the air is typically blown through slots or holes around the outside of a disk or oval shaped platform, giving most hovercraft a characteristic rounded-rectangle shape. Typically this cushion is contained within a flexible "skirt", which allows the vehicle to travel over small obstructions without damage. Vehicles designed to travel close to but above ground or water. These vehicles are supported in various ways. Some of them have a specially designed wing that will lift them just off the surface over which they travel when they have reached a sufficient horizontal speed (the ground effect). Hovercrafts are usually supported by fans that force air down under the vehicle to create lift, Air propellers, water propellers, or water jets usually provide forward propulsion. Air-cushion vehicles can attain higher speeds than can either ships or most land vehicles and use much less power than helicopters of the same weight. Air-cushion suspension has also been applied to other forms of transportation, in

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

particular trains, such as the French Aero train and the British hover train. Hovercraft is a transportation vehicle that rides slightly above the earthâ„¢s surface. The air is continuously forced under the vehicle by a fan, generating the cushion that greatly reduces friction between the moving vehicle and surface. The air is delivered through ducts and injected at the periphery of the vehicle in a downward and inward direction. This type of vehicle can equally ride over ice, water, marsh, or relatively level land.

Figure. 1.1 – Air Cushion Vehicle

2. LITERATURE REVIEW

2.1. HISTORY OF AIR CUSHION VEHICLE

There have been many attempts to understand the principles of high air pressure below hulls and wings. To a great extent, the majority of these can be termed "ground effect" or "water effect" vehicles rather than hovercraft. The principal difference is that a hovercraft can lift itself while still, whereas the majority of other designs require forward motion to create lift. These active-motion "surface effect vehicles" are known in specific cases as ekranoplan and hydrofoils. The first mention in the historical record of the concepts behind surface-effect vehicles that used the term hovering was by Swedish scientist Emanuel Swedenborg in 1716. In 1915 Austrian Dagobert Müller (1880–1956) built the world's first "water effect" vehicle. Shaped like a section of a large aerofoil (this creates a low pressure area above the wing much like an aircraft), the craft was propelled by four aero engines driving two submerged marine propellers, with a fifth engine that blew air under the front of the craft to increase the air pressure under it. Only when in

INTERNATIONAL JOURNAL of
RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

motion could the craft trap air under the front, increasing lift. The vessel also required a depth of water to operate and could not transition to land or other surfaces. Designed as a fast torpedo boat, the Versuchsgleitboot had a top speed over 32 knots (59 km/h). It was thoroughly tested and even armed with torpedoes and machine guns for operation in the Adriatic. It never saw actual combat, however, and as the war progressed it was eventually scrapped due to lack of interest and perceived need, and its engines returned to the Air Force. The theoretical grounds for motion over an air layer were constructed by Konstantin Eduardovich Tsiolkovskii in 1926 and 1927. In 1929, Andrew Kucher of Ford began experimenting with the "Levapad" concept, metal disks with pressurized air blown through a hole in the center. Levapads do not offer stability on their own, several must be used together to support a load above them. Lacking a skirt, the pads had to remain very close to the running surface. He initially imagined these being used in place of casters and wheels in factories and warehouses where the concrete floors offered the smoothness required for operation. By the 1950s, Ford showed a number of toy models of cars using the system, but mainly proposed its use as a replacement for wheels on trains, with the Levapads running close to the surface of existing rails. In 1931, Finnish aero engineer Toivo J. Kaario began designing a developed version of a vessel using an air cushion and built a prototype Pintaliitäjä (Surface Soarer), in 1937.[5] Kaario's design included the modern features of a lift engine blowing air into a flexible envelope for lift. Kaario never received funding to build his design, however. Kaario's efforts were followed closely in the Soviet Union by Vladimir Levkov, who returned to the solid-sided design of the Versuchsgleitboot. Levkov designed and built a number of similar craft during the 1930s, and his L-5 fast-attack boat reached 70 knots (130 km/h) in testing. However, the start of World War II put an end to Levkov's development work. During World War II, an engineer in the United States of America, Charles Fletcher, invented a walled air cushion vehicle. Because the project was classified by the U.S. government, Fletcher could not file a patent.

3. METHODOLOGY

3.1. LAW'S ACTS IN AIR CUSHION VEHICLE

3.1.1. ARCHIMEDES' PRINCIPLE OR THE LAW OF BUOYANCY

In order to lift the Air cushion vehicle, the pressurized air must now push against the surface of the water. If you tried pushing your hand into a sink full of water, your hand would sink into the water. What keeps the Air cushion vehicle from sinking as well? The answer to this comes from one of the oldest established principles in the history of science: **Archimedes' Principle** or **the Law of Buoyancy.**

According to legend Archimedes was struck by this principle while taking a bath when he noticed that the volume of water displaced was equal to the volume of his body. Overjoyed by his discovery, he jumped out of the bathtub and ran through the streets naked shouting, “Eureka! Eureka!” (Greek for “I've found it! I've found it!”) Developed in 250 BC, this principal explains why some objects floats in water while others sink. The principle states the following:

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

"When a body is immersed in fluid at rest it experiences an upward force or buoyant force equal to the weight of the fluid displaced by the body**"**.

Notice when you get into a bathtub, the level of the water rises. This is because your body is now taking up some of the space where the water used to be. The water has to go somewhere else when it is pushed out of the way, so it goes up, making the water level rise. You've just displaced that amount of water. Archimedes' Principle says that a buoyant force will push upwards on you when you're in the water, and the strength of the force will be equal to the weight of the water that you pushed out of the way when you got in. The same thing happens with boats. When a boat is placed in water, part of the boat goes beneath the surface of the water and pushes the water out of the way. According to Archimedes' Principle, this results in a buoyant force that pushes up on the boat. The magnitude, or strength, of the force is equal to the weight of the water that would have filled the space that is now taken up by the boat. The boat floats in the water because this upward buoyant force is equal to the downward weight of the boat. In order to do calculations using this principle, we need to know the weight of a certain volume of water that is displaced, or the weight density of water.

Weight Density = Weight ÷ Volume

The weight density of water is about 62.42 pounds per cubic foot (lb/ft^3). A cubic foot is a unit of volume equal to the volume inside a box whose sides are 1 ft long. In SI units (System International), the weight density of water is about 9806 Newton's per cubic meter (N/m^3).

3.1.2. NEWTON'S THIRD LAW

The third law states that all forces exist in pairs: if one object A exerts a force F_A on a second object B, then B simultaneously exerts a force F_B on A, and the two forces are equal and opposite: $F_A = -F_B$. The third law means that all forces are interactions between different bodies, and thus that there is no such thing as a unidirectional force or a force that acts on only one body. This law is sometimes referred to as the action-reaction law, with F_A called the "action" and F_B the "reaction". The action and the reaction are simultaneous, and it does not matter which is called the action and which is called reaction; both forces are part of a single interaction, and neither force exists without the other. The two forces in Newton's third law are of the same type (e.g., if the road exerts a forward frictional force on an accelerating car's tires, then it is also a frictional force that Newton's third law predicts for the tires pushing backward on the road). From a conceptual standpoint, Newton's third law is seen when a person walks: they push against the floor, and the floor pushes against the person. Similarly, the tires of a car push against the road while the road pushes back on the tires—the tires and road simultaneously push against each other. In swimming, a person interacts with the water, pushing the water backward, while the water simultaneously pushes the person forward—both the person and the water push against each other. The reaction forces account for the motion in these examples. These forces depend

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

on friction; a person or car on ice, for example, may be unable to exert the action force to produce the needed reaction force.

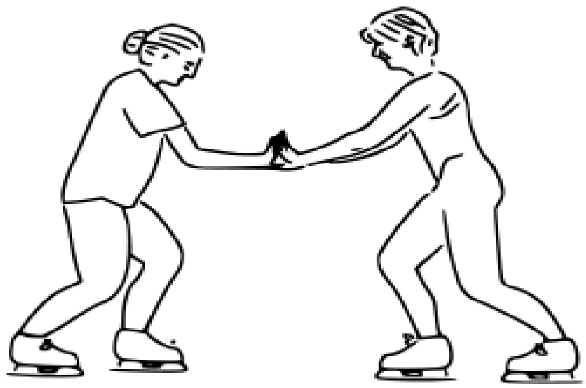

Figure. 3.1 - Newton's third law.

3.1.3. AERODYNAMICS

Aerodynamics is defined as the branch of fluid physics that studies the forces exerted by air or other gases in motion. Examples include the airflow around bodies moving at speed through the atmosphere (such as land vehicles, bullets, rockets, and aircraft), the behavior of gas in engines and furnaces, air conditioning of buildings, the deposition of snow, the operation of air-cushion vehicles (hovercraft), wind loads on buildings and bridges, bird and insect flight, musical wind instruments, and meteorology. For maximum efficiency, the aim is usually to design the shape of an object to produce a streamlined flow, with a minimum of turbulence in the moving air. The behavior of aerosols or the pollution of the atmosphere by foreign particles are other aspects of aerodynamics.

3.2. ELEMENTS OF AIR CUSHION VEHICLE

3.2.1. PLATFORM

The base of any ACV is made up liken this that it can protect the vehicle from any causes. The base is also too strong which can bear the payload and also the other load for which it will be designed. When the ACV is made for the commercial and rescue purpose in which are the land surfaces are get covered then the base should be taken strong. The platform is a base of the Air cushion vehicle The base is the thing on which the all equipment of the Air cushion vehicle is mounted. The base is basic requirement of the Air cushion vehicle on which all the design will take place. The base is taken by us is made of wood, wood have the elasticity when the load is applied so we take the wooden platform.

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

Figure. 3.2.1 wooden platform

Specification of Platform:

Length of platform - 4 ft.
Width of platform - 2 ft.
Material of platform - Wood
Thickness of platform - 6 mm

3.2.2. SKIRT

Despite the momentum curtain being very effective the hover height was still too low unless great, and uneconomical, power was used. Simple obstacles such as small waves, or tide-formed ridges of shingle on a beach, could prove to be too much for the hover height of the craft. These problems led to the development of the 'skirt'. The skirt is a shaped, flexible strip fitted below the bottom edges of the plenum chamber slot. As the hovercraft lifts, the skirt extends below it to retain a much deeper cushion of air. The development of the skirt enables a hovercraft to maintain its normal operating speed through large waves and also allows it to pass over rocks, ridges and gullies. The skirt of a hovercraft is one of its most design sensitive parts. The design must be just right or an uncomfortable ride for passengers or damage to the craft and the skirts results. Also, excessive wear of the skirt can occur if its edges are flapping up and down on the surface of the water. The skirt material has to be light flexible and durable all at the same time. For the skirt to meet all of its requirements the design and use of new materials has slowly evolved. The current skirts use Infringers at the lower edge of the skirt envelope which can be unbolted and replaced. By doing this there is a quick and easy way to counter the effects of wear without having to replace the whole skirt structure Skirt is the material which is made by the gelatin. The skirt is taken to hold the air pressure which is generated inside the base or downside

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

of the platform. The skirt is mounted on the base by the nail or other thing whi9ch can bear the pressure of air. The skirt is also taken by the material which can bear the pressure of air.

Figure 3.2.2: Skirt

3.2.3. BLOWER

Blower may refer to:
Air blowers generally use centrifugal force to propel air forward. Inside a centrifugal air blower is a wheel with small blades on the circumference and a casing to direct the flow of air into the center of the wheel and out toward the edge. The design of the blades will affect how the air is propelled and how efficient the air blower is. Blade designs in air blowers are classified as forward-curved, backward-inclined, backward-curved, radial and airfoil.

Figure 3.2.3: Packet of Air Blower.

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

Forward-Curved Air Blowers
Forward-curved blowers are impulse devices with blades that are curved in the direction of rotation. The blower accelerates air to a high velocity while rotating at a low speed. Forward-curved blower wheels spin at relatively low speeds and produce high volumes of air at low static pressures. This type of blower is incapable of operating at the speeds necessary to create high static pressures because of its lightweight construction. Still, forward-curved blowers are the most common type of air blower because they propel the most air volume in relation to blower size and speed.

Backward-Inclined and Backward-Curved Air Blowers
A backward-inclined blower, operating at roughly twice the speed of a forward-curved air blower, has flat blades that slant away from the direction of travel. This type of blower is highly efficient (low horsepower requirement) and has a rugged construction suitable for high static pressure applications. This type of air blower is best used in locations where the air is either clean or mildly contaminated. Similar to this style is a backward-curved air blower. The blades of a backward-curved blower are a single thickness throughout and curve away from the direction of travel. These blades are sturdier than backward-inclined blades and can be used in corrosive and erosive environments.

Radial Air Blowers
Radial blowers are designed for industrial use in small exhaust systems. These air blowers are capable of handling air that contains bits of dirt, grit, lint and other foreign particles while still maintaining a high-pressure supply of air for conveying and cooling. Their use in particle-laden air means that this type of blower is generally designed to be self-cleaning. Radial air blowers have the lowest efficiency levels because the blades have no curve or lean and are perpendicular to the wheel's rotation. Think of a paddleboat racing a boat with an outboard motor. No matter how fast the paddle spins, it will not catch up to the boat with the outboard motor.

Airfoil Air Blowers
Airfoil blowers have the most efficient design of all air blowers. Their blades have an airfoil shape that is wide at the center and curves down to narrow edges. Airfoil blowers are extremely efficient because they require lower horsepower levels to operate. This type of blower is used in clean air situations.

Types of blowers
Blowers can achieve much higher pressures than fans, as high as 1.20 kg/cm2 . They are also used to produce negative pressures for industrial vacuum systems. The centrifugal blower and the positive displacement blower are two main types of blowers, which are described below. 1.Centrifugal blowers: Centrifugal blowers look more like centrifugal pumps than fans. The impeller is typically gear-driven and rotates as fast as 15,000 rpm. In multi-stage blowers, air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient. Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm2 , but can achieve higher pressures. One characteristic is that airflow tends to

INTERNATIONAL JOURNAL of
RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

drop drastically as system pressure increases, which can be a disadvantage in material conveying systems that depend on a steady air volume. Because of this, they are most often used in applications that are not prone to clogging. 2.Positive-displacement blowers : Positive displacement blowers have rotors, which "trap" air and push it through housing. These blowers provide a constant volume of air even if the system pressure varies. They are especially suitable for applications prone to clogging, since they can produce enough pressure (typically up to 1.25 kg/cm2) to blow clogged materials free. They turn much slower than centrifugal blowers (e.g. 3,600 rpm) and are often belt driven to facilitate speed changes.

Figure 4: Blower

Specification of Blower:

Voltage - 220 V
Frequency - 50 Hz
Wind Pressure - 2.8 m3 / min.
Speed - 0 – 13000
Weight - 2 kg.

3.2.4. AIR INLET HOLE

Air inlet hole is the hole which is provide in the base offset from the center of the base. In the hole the nozzle of the blower is fitted,. Which throw the air in the skirt so that the air cushion will generated inside the base. The diameter of the hole is same to the diameter of the blower and if there is some gap then it is filled by some packing. It is important to make this hole leak proof if the air is come through this hole to the outside then it will create less cushion in the downward side whi8ch cause the high friction, which create the problem in the hovering.

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

Figure 3.2.4: Air inlet hole.

The hole is taken to the front of the passenger so that it can control the ON / OFF to the blower according to the need. The nozzle of the blower do not go to the outside from the depth of the platform, it will fix to the same level which can be done by the physical sensing.

3.2.5. SUPPORTING STRIP

The supporting strips as the name specify it support the structure. These strips are used in the top of the platform which give some strength to the platform. When the air pushes the land surface and give the buoyancy force to the whole unit it also affect the platform, it give some lump to the platform to get rid of this we attach the two strip or angle of aluminum from the same distance from the air inlet hole. The length of the strip is 3 ft.

Figure 3.2.5: Supporting strip.

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

The aluminum strip is because the weight of the aluminum is low and in air cushion vehicle always try that minimize the payload of the unit.

3.3. PROPULSION SYSTEM

The propulsion system as the name specifies to propel some thing by the application of the force. The simple meaning of propulsion is to give the motion in the forward direction. This system is useful in every thing which we want to give motion, in air cushion vehicle the propulsion system is use to move it. The propulsion system is placed in the backside of the unit. The propulsion system is used compressed airs which sucked from the one side by the compressor or other thing and compress it to a high pressure and eject it from the second end with a high velocity which move the unit to the forward side or direction. The concept of the propulsion system is based on the principle of the Newton's Third Law according to which –

"Each and every action has equal and opposite reaction".

For example - If you press a stone with your finger, the finger is also pressed by the stone.

Figure 3.3 propulsion system

4. WORKING PRINCIPLE OF AIR CUSHION VEHICLE

Hovercraft Principle:

Hovercraft is one of the most unusual vehicles that you can see. Moves on an air cushion of slightly pressurized air that makes it easily overcomes any slight unevenness and obstacles. Because the hovercraft moves only after air and earth will affect virtually, no matter what the surface flies. It can run on sand, asphalt and the water are no problem for him or swamps and snow. They belong to a group of amphibians. Since the air under the hovercraft is not changed in

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

transit between different surfaces (eg between sandy beaches and water) can not tell any difference. Hovercraft dynamics is more aircraft than ships and automobiles.

Air cushion:

Hovercraft floats on a cushion of air that is chased by a propeller craft. After starting to lift the hovercraft and is ready to ride. The size of stroke ranges from 15 cm in the smallest personal hovercraft to 2.8 meters for large transport machines. The air pocket under the hovercraft is surrounded by plastic to air from leaking out from under the hovercraft. Implementation of the mantle differ may be either in the form of a compact bag or can be divided into individual cells - so-called segments. Most professional hovercraft using Segmented casing, because each piece is in transit through the inequality diverges separately. It is very convenient, because the lifter loses only a very small amount of air.

Movement of Hovercraft:

After the hoist lifter can move forward. It must provide a separate air operator, which takes a hovercraft. Many of the vessels used to move a separate engine, but some have only one engine for both functions - that is, for blowing air under the hovercraft and also to move forward. In this case, the airflow split propeller, which in part drives the flyer for floatability, while majority of the air is used to move the hovercraft.

Control Hovercraft:

Control hovercraft is done through a system of rudders, which are located behind the propeller. The rudders are controlled by the pilot using the handlebars. Another way to significantly modify the movement of hovercraft is carrying weight.

5. RESULTS AND ANALYSIS

5.1. CALCULATION

NOMENCLATURE

a = Area
l = length of platform
b = Width of platform
Dc = Co-efficient of discharge
P = Pressure

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

ρair = Density of air
Exit = Velocity exit
Q = Flow rate of air
Weight of the ACV = 6 kg.
Length of the ACV = 4 feet
Width of the ACV = 2 feet
Area = Length x Width
= 4 x 2
= 8 ft^2
Pressure (p) = Force / Area
= 6 kg / 8 ft^2
= 0.75 kg/ ft^2
Area of the Air Cushion Vehicle gap = Length x Height
= 1.21 x 0.0124
= 0.0153 m^2
Velocity Exit = Dc $\sqrt{}$ (2 x p / ρ air)
= 0.53 x $\sqrt{}$ (2 x 0.75 / 1)
= 0.649 m / sec.
Cushion Pressure = 1.3 p
= 1.3 x 0.75
= 0.975 kg / ft^2

Flow rate of air Q = Area of air cushion vehicle gap x Velocity exit
= 0.0153 x 0.649
= 0.0099 m^3 / sec.

6. APPLICATIONS

By using Air cushion vehicle no need of change of vehicle according to the land.
1. A hovercraft travel over the surface of water without concern for depth or hidden obstacles.
2. It is safe around swimmer as there is no propeller in water.
3. It can load and unload peoples and equipments on land.
4. It can travel against a current of river with no reduction of speed.

7. COST ESTIMATION

S.No.	PERTICULAR	AMOUNT (IN RUPEES)
1	Plywood (4 x 2 ft)	350/-
2	Gelatin (5 x 6 ft)	200/-

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

3	Tap	30/-
4	Aluminum Angle (6 ft)	190/-
5	Blower 1	1200/-
6	Blower 2	950/-
7	Blower 3	950/-
8	Wire (20 ft) + Plug	90/-
	Total Cost	3960/-

8. CONCLUSION

The conclusion if our project is that we lift the weight above our expectation the blow of air from the narrow hole with high pressure and high RPM inside the skirt create the lift. When the air is blow inside the skirt with pressure, then the air is circulated in the skirt when the air is circulated the air is get the small hole outlet which create the pressurize the earth surface the which impact the earth surface and create the lift and also reduce the friction between the earth surface and the unit. The uni9t is run on the surface due less friction. Hovercrafts are generally simple mechanisms in theory. Yet the process from theory to manifestation is not as easy as it may seem. A plethora of problems exist and must be faced in order to attain a well functioning hovercraft. The plans and designs must be flawless. One must take under consideration the weight and the shape of each component in order to avoid problems such as instability and dysfunction. This is a marvelous machine which greatly cuts down the friction which in turn helps it to attain greater speed and more stability. Varieties of problems and factors have to be taken into account in designing and constructing a hovercraft. The difficulties involved in maintaining stability and functional competency has limited the application to only transportation or for military purpose. The cost involved in the developing of a hovercraft is also another impediment to the widespread use of this machine.

9. FUTURE DEVELOPMENT

By using the hover principle many designs have arise. One is the hover concept by replacing the cushion of low pressure air as inform the modern Hovercraft by high pressure pad it was thought that the pads of high pressure could replace the wheels of the car. but there are two difficulties.
1. It is difficult to lift
2. New method of propulsion is required

Then moved towards Hover train. Here rails provide smooth surface for high pressure air and guidance from the track overcomes the problem of steering. The future of hovercraft seems

INTERNATIONAL JOURNAL of RESEARCH –GRANTHAALAYAH
A knowledge Repository
Science

uncertain, but there is a good chance there will be huge hover ports all over the world, like the one in the picture. Thinner hovercraft might be built so civilians can drive safely on roads. It also seems likely that the larger hover vehicles will become larger than ever! Hovercraft are likely to be capable of high flight.

10. REFRERNCES

[1] Mantle, P. J., "Air Cushion Craft Development", David W. Taylor Naval Ship Research and Development Center, Bethesda, Maryland, DTNSRDC-80/012,1980.

[2] Chung, .1., "Theoretical Investigation of Heave Dynamics of an Air Cushion Vehicle: Bag and Finger Skirt", Ph.D. dissertation. Institute for Aerospace Studies, University of Toronto, 1997.

[3] Nah, Seung-Hyeog, "The Development of an Expert System for Aircraft Initial Design (DESAID)", Ph.D. dissertation, Cranfield Institute o f Technology, 1991.

[4] Perez, R. E., "Aircraft Conceptual Design Using Genetic Algorithms", 8"' AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, AIAA paper No., AIAA-2000-4938, 2000.

[5] Chung, J. and Jung, T., "Optimization of an Air Cushion Vehicle Bag and Finge Skirt Using Genetic Algorithms", accepted to Journal o f Aerospace Science and Technology, Elsevier 2003.

[6] Ryan G. W., "A Genetic Search Technique for Identification of Aircraft Departures" NASA Contractor Report 4688, Dryden Flight Research Center, 1995.

[7] Moran, D.D., "Cushion Pressure Properties of a High Length-to-Beam Ratio Surface Effect Ship," NSRDC Report SPD-600-01, 1975.

[8] Sullivan, P.A., Charest, P.A. and Ma, T., "Heave Stiffness of an Air Cushion Vehicle Bag and Finger Skirt," Journal of Ship Research, Vol. 38, No. 4, Dec. 1994.

[9] Chung, J. and Sullivan, P.A., "Effects of Unsteady Fan Response on Heave Dynamics of an Air Cushion Vehicle Bag and Finger Skirt," AIAA-97-3512, 1997.

[10] *Doctors, L.J., "Nonlinear Motion of an Air-Cushion Vehicle over Waves," Journal of Hydronautics, Vol. 9, No. 2, April 1975, pp. 44-57.*