# MODELLING AND STATIC STRUCTURAL ANALYSIS OF HOVER CRAFT ASSEMBLY UNDER CERTAIN STATIC LOAD CONDITIONS

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## ABSTRACT

*This is the design of a small-scale working model hovercraft which providing fully hovercraft basic functions. Basically the hovercraft design and fabrication process is quite similar to boat, ship, or aircraft design. In this report, I had made the entire analysis requirement, formulas for thrust and lift, drag components calculation and other important parameters to realization the design of the working model hovercraft. On the other hand, this report is aim to provided objective and scope of the research, the literature review study, research methodology, and fem analysis on hybrid joint structures of the model with result analysis and conclusion as part of requirement in submitted the report. Although hovercraft research and development is still new technology and no domestic consumption in this technology, but through this project it can help the industry a step further. It is because this project can categorized as successful and working as expected.*

***Keywords:*** *aircraft design, Fem Analysis, Hybrid joint Structures.*

## 1.0 INTRODUCTION

Over the centuries there have been many efforts to reduce the element of friction between moving parts. A hovercraft is a relatively a new means of transportation. The concept of the hovercraft was born when engineers came up with an experimental design to reduce drag on ships. The revolutionary idea was to use a cushion of air between boats and the water that they plowed through in order to reduce friction. This idea eventually led to what is known today as the hovercraft, basically a vehicle that uses 1 or more fans to float on a cushion of air. These fans serve a dual purpose, to push air below the craft and forcing it off ground, and to create forward thrust by pushing air out the back of the craft. The first recorded design for an air cushion vehicle was by Swedish designer and philosopher, Emmanual Swedenborg, in 1716. The project was rather short lived however. In the mid 1870s, Sir John Thornycroft built a number of model craft to check the 'air cushion' effects and even filed patents involving air lubricated hulls. Both American and European engineers continued to work n the problems of designing practical craft.

**FIGURE 1.1** A LARGE HOVERCRAFT FERRY IN ENGLAND CALLED THE SN.R4.

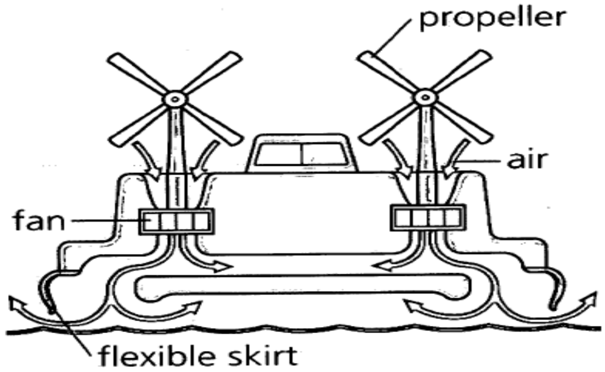



**FIGURE 1.1 WORKING MODEL OF HOVERCRAFT**

## SCOPE OF RESEARCH

a) To find the design fundamental for small working model hovercraft.

b) Make the research for small hovercraft background and construction.

c) Find principles dimension for hovercraft that will design and make comparison with other hovercraft.

d) To find drag component and lift force that stride to hovercraft.

e) To find the best material used to build this small hovercraft.

f) To recognize all hovercraft applications and limitations and also to define a small hovercraft in their classification.

• Lift- Lift is the air cushion beneath the hull surrounded by the skirt.

• Thrust- Thrust is the force that will fight and win Drag, inducing movement to the hovercraft.

• Drag- Drag is the force that hinders forward motion.

## 1.2 PRINCIPLE OF WORKING:

The principle of working of a Hovercraft is to lift the craft by a cushion of air to propel it using propellers. The idea of supporting the vehicle on a cushion of air developed from the idea to increase the speed of boat by feeding air beneath them. The air beneath the hull would lubricate the surface and reduce the water drag on boat and so increasing its speed through water. The air sucked in through a port by large lifting fans which are fitted to the primary structure of the craft. They are powered by gas turbine or diesel engine. The air is pushed to the under side of the craft. On the way apportion of air from the lift fan is used to inflate the skirt and rest is ducted down under the craft to fill area enclosed by the skirt.

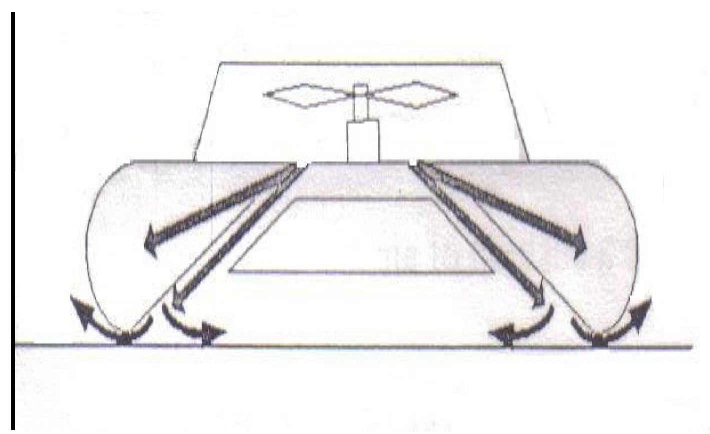


Figure 4: underside of the craft

## RESEARCH OBJECTIVES

The research objectives of this project are to design of a small scale working model hovercraft under the following condition:

• Small crafts have a single engine with the drive through the speed.

• One engine used to drives the fan responsible for lifting the vehicle.

• The other forces air from.

Can be powered by one or more engines

## 2.0 LITERATURE REVIEW:

A wind tunnel is a tool used in aerodynamic research to study the effects of air moving past solid objects. A wind tunnel consists of a closed tubular passage with the object under test mounted in the middle. A powerful fan system moves air past the object; the fan must have straightening vanes to smooth the airflow. The test object is instrumented with a sensitive balance to measure the forces generated by airflow; or, the airflow may have smoke or other substances injected to make the flow lines around the object visible. Full-scale aircraft or vehicles are sometimes tested in large wind tunnels, but these facilities are expensive to operate and some of their functions have been taken over by computer modelling. In addition to vehicles, wind tunnels are used to study the airflow around large structures such as bridges or office buildings.

**[1] F.K. Lu et.al [2008]** which was able to start a supersonic wind tunnel very quickly without any overshoot of the stagnation pressure. The control system consists of a multifunction PC board, a pressure transducer and an automatic valve. An ideal valve opening profile for a particular test was developed based on test data and stored in system memory before a test. After several tests, the pressure disturbances in the plenum chamber are typically reduced to one percent of the stagnation pressure.

**[2] A. Jadlovska et.al [2009]** focused on modeling and control of nonlinear dynamical system Ball & Plate using Matlab/SIMULINK. The closed loop feedback control structure of PID controller was used for the purpose of control. The designed non linear model of the dynamical system was tested and verified on real model Ball and Plate. The functional schematic for nonlinear model was designed in SIMULINK, where as parameters of model, initial conditions, operating point and PID control algorithms were realized in Matlab. The verification on the real model Ball and Plate was satisfying in the case of control into required position. Although applying of PD controller for control of the simulation model showed better result, its usage for control of the real model was insufficient. Modern engineering control methods can be used in future control problem for solving the real models of dynamical systems.

**[3] Jun-JieGu [2008]**analyzed the ideal change in relationship between the error of the control object and the control parameters. The nonlinear functions are presented to form a nonlinear PID controller, whose parameters are tuned in SIMULINK. The nonlinear PID controller is applied to one main stream temperature control system. The simulation results show an improvement in performance for the nonlinear PID controller than traditional linear PID controller.

**[4] P. Dostal et.al [2011]** presented a continuous-time nonlinear adaptive control of a continuous stirred tank reactor. The control strategy was based on an application of the controller consisting of a linear and nonlinear part. The derivation of static nonlinear part was by inversion and consecutive polynomial approximation of a measured or simulated input-output data. The dynamic linear part is designed based on approximation of nonlinear elements in the control loop. The polynomial approach with the pole assignment method was used in the control design procedure. Testing of the nonlinear model of the CSTR by computer simulation demonstrated the applicability of the presented control strategy and its usefulness in strongly nonlinear regions. The control strategy is also expected to be suitable for other similar technological process.

## 3.0 MODELLING OF HOVER CRAFT:

**Lift force:** The lift force that we want to produce in our hovercraft is a force that is equal to or greater than the weight of the hovercraft. Blowing air into the hovercraft's skirt, creating a high-pressure pocket, produces lift. Since the pressure in the skirt is greater than the pressure produced by the weight of the hovercraft, an upward force is created.

Weight of craft, w = Lift force, Fcu

Fcu = w = PcuAc + JjLj Sin qj

Where,

Jj = The momentum flux of the air jet per unit length of the nozzle

Lj = The nozzle perimeter

Tj = The thickness of the jet/nozzle width

Hj = The lift height

Rar = The average radius of the curvature of the length

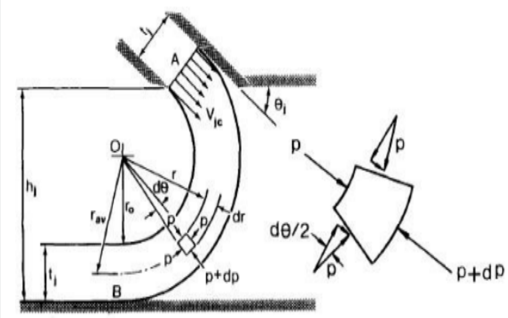
Pcu = The cushion pressure

Acu = Cushion area

Qj = Total volume flow

Paj = The power required (lift power)

qj = The angle of the nozzle from the horizontal




Geometry of Peripheral Jet System.

**FIGURE 3.1 GEOMETRY OF PERIPHERAL JET SYSTEM**

### 3.2 HOVERCRAFT SPECIFICATION

Length=4 m

Width=1.25 m

Cross sectional area of Hovercraft=4*1.25=5 $m^2$

Weight of Hovercraft-Total weight= 325 kg

Normal operating speed-V=40 km/h

Power requirement = 200 kW

Thrust requirement = 7000

N. Skirt area = 5 $m^2$

Let maximum weight of crew = 700 kg

Also weight of craft = 325 kg

Let the nozzle angle to the horizontal = 71.20

Let the lift height = 0.2 m = hj

Thickness of jet, tj = 24 inch

tj= 0.6096 m

Weight force of craft and pilot,

W= mg = (700 + 325) kg × 9.81 m/s2

W = 10545.75 N = Fcu

Cushion Area, Acu = L × W = 4 ×1.25

Acu = 5 m2

Fcu = PcuAcu +JjLjsinqj = W

Jj = Pcu × rav

$$rav = \frac{hj}{1+\cos qj}$$

$$\frac{0.2}{1+\cos 71.2}$$

where, hj = 0.2 m

Jj= 0.1513 Pcu

Lj =π × tj = π × 0.6096

Lj =1.9151

Fcu = PcuAcu +JjLjsinqj = W

10545.75 = (Pcu * 5) + (0.1513 Pcu x 1.9151 x sin 71.2) = 5 Pcu + 0.2743 Pcu

10545.75 = 5.2743 Pcu

Pcu = 1999.46 N/$m^2$

The expression relating cushion pressure Pcu and total Pressure of the jet Pj is given

Pcu/Pj = 1- 3.1641 × $10^{-4}$

Pj = Pcu/[1-3.1641 × $10^{-4}$]

Pj = 2000 N/$m^2$

Total volume flow Qj (i.e. air flow rate by volume) is given by Qj = 15.95 $m^3$/s

(i.e. assuming dry air density ρ = 1.2754 kg/$m^3$)

Power required is given by; Paj = Pj × Qj

= 2000 × 15.95 = 31,909 watts

Paj = 31.909 Kw

When designing our hovercraft we need to take lift into consideration. The cross sectional area and the weight of the hovercraft will determine how much lift our hovercraft will need to produce. Therefore, considering the lift required is essential when determining the size and weight of our hovercraft. We must also design our skirt so that it contains the air, but also allows air to escape from the bottom when the pressure is too high. To ensure perfect balance, we must control the hovercraft's pitch, vertical movement of the nose, and yaw, horizontal movement of the nose. It is vital that the pressure is distributed evenly throughout the skirt and that the center of mass of the hovercraft is properly supported so that no unwanted moment will be created

### 3.3 THRUST FORCE

Thrust, which is created by the propulsion system, is the force that pushes the hovercraft forward. Having maximum thrust is critical for our hovercraft, as we are designing it so that it may travel a certain distance in the smallest amount of time.

The momentum of an object is given by

Q=m*v

Where, Q is the object's momentum in kg•m/s,

m is the mass of the object in kg

v is the velocity of the object in m/s

The mass of the object is given by

mass = Weight/gravitational force

m = 3188.25/9.81

m = 325 kg

According to Newton's Second Law, the force acting on an object is proportional to the rate of change of the object's momentum.

The force on an object can therefore be written as:

Ft=m (Vo-Vi)/(t2-t1)

Where, Ft=Thrust force

m= mass of the hovercraft

Vo=outlet velocity Vi=initial velocity

t2=final velocity t1=initial velocity

Calculation of the mass flow rate

ṁ= ρvA

Where, ṁ is measured in kg/s,

ρ is the fluid density in kg/m3 ,

v=velocity of the hovercraft,

A is the cross-sectional area of the propulsion system, such as a fan, in m2 . ṁ = 1.225*40*5 = 245 kg/s

The thrust force can then be written as: Ft = ṁ (Ve-Vi) = 245*(15-0) = 3675 N

Where, Vi is the entrance velocity

Ve is the exit velocity, to and from the propulsion system, in m/s.

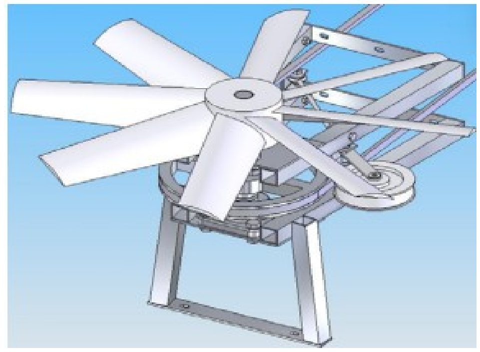


**FIGURE 3.2 SKIRTDESIGN**

## STEERING:

Must meet turning rate

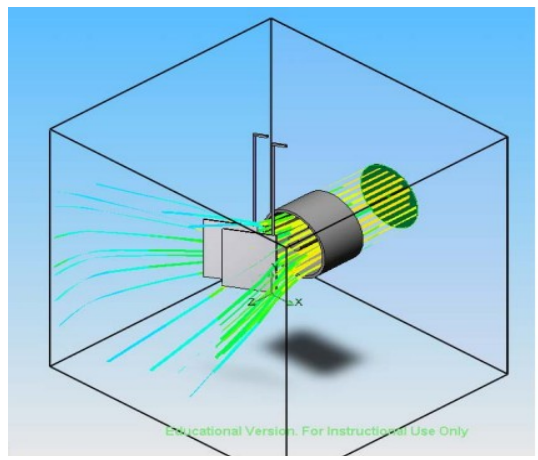



**FIGURE 3.3 RUDDER**

Flat plate selected „

36 inches tall (diameter of duct)

24 inches long

Modular design „

Contains thrust mechanism „

Contains steering control surfaces

## 4.RESULTS:

### 4.1 FACTOR OF SAFETY ALONG Y-AXIS

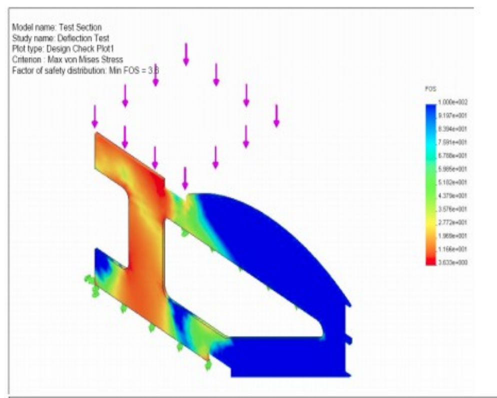



**FIGURE 4.1 FACTOR OF SAFETY ALONG Y-AXIS**

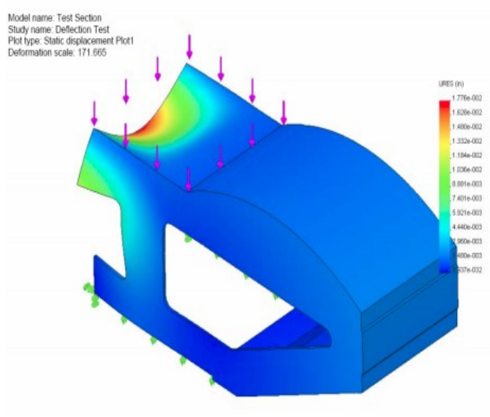
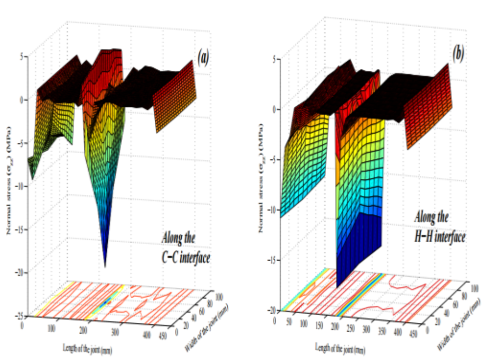
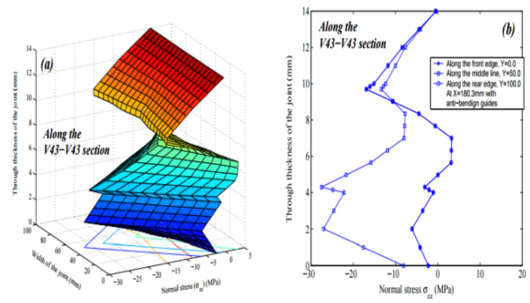
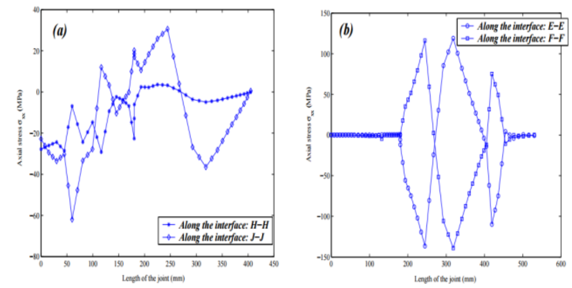



**FIGURE 4.2 TOTAL DEFORMATION**




## 5.0 CONCLUSIONS:

The hovercraft base model has been taken as a design model, its size and performance has been studied with the available journals and books. The base structure was designed and its lift, thrust and drag has been determined. The Clark Y wing was attached to hovercraft to produce the lift which was already produced by fan. Hovercraft with winged model design will be carried out at an optimized angle of attack. The performance measures of hover flight will be done using Computational Fluid Dynamic(CFD) software's and the total coefficient of lift to drag ratio will be calculated against the various angle of attack, manipulating the initial thrust required to make lift and opting maximum propulsion force for forward movement. The scaled wooden model was developed and experimentally analysed by using wind tunnel experiment. Also a three dimensional modelling of a GRP-Steel hybrid joint that forms a structural component between the hull and the super-structure in the hovercraft is attempted for the first time in the final study. Three dimensional analyses has resulted in fresh understanding that the normal stress along the interface layer is not uniform across the width of the hybrid joint. It is suggested that the more refined FE mesh model should be analysed for further understanding of the stresses that cause failure.

## FUTURE SCOPE

Hovercrafts have numerous uses in the world today, from commercial to military and even to recreational purposes such as racing. As an all-terrain vehicle, a hovercraft is able to reach places that are hard to get to with other more conventional vehicles. In addition, radio communication is also obviously very prevalent in the world today for use by governments, the entertainment industry, advertisers, and also the military. It can be used to control unmanned vehicles so that a human pilot does not have to risk his or her life.

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