MODELING AND STRUCTURAL ANALYSIS OF HOVERCRAFT ASSEMBLY

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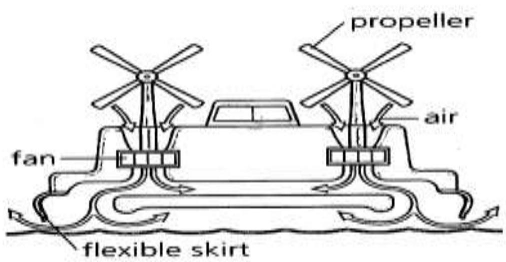
ABSTRACT
This is the design of a small-scale working model hovercraft which providing fully hovercraft basic functions. Basically the hovercraft design and fabrication process is quite similar to boat, ship, or aircraft design. In this report, I had made the entire analysis requirement, formulas for 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.

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. Not until early 20th century was a hovercraft possible because only the internal combustion engine had the very high power to weight ratio suitable for hover flight. The commercially viable model of a hovercraft was designed in *1955* by the English inventor Christopher Cockerell. It's different from traditional vehicles because it has no surface contact when it's in motion. Cockerell continued work on hovercrafts through the 1960's, was knighted for his services to engineering in 1969 and is credited with coining the word hovercraft to describe his invention. Since then, many types of land, marine and amphibious air cushion vehicle have developed. Hovercraft has paved its way for new opportunity on Malaysia manufacturing sector. Its major introduction is to assist fire and rescue department and was produced by AFE manufacturing company with Japanese technology collaboration.

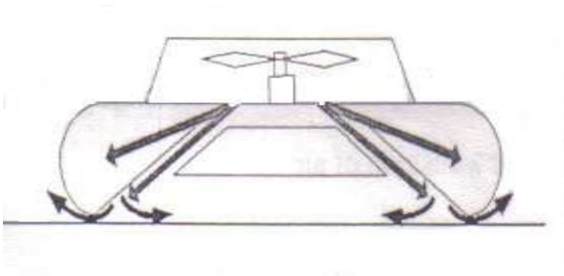
A Hovercraft is a vehicle that flies like a plane but can float like a boat, can drive like a car but will traverse ditches and gullies as it is a flat terrain. A Hovercraft also sometimes called an air cushion vehicle because it can hover over or move across land or water surfaces while being held off 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.



Working Model of Hovercraft

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.



At the point when the pressure equals the weight of the craft, the craft lifts up and air is escaped around the edges of the skirt. So a constant feed of air is needed to lift the craft and compensate for the losses. Thus craft is lifted up. After the propulsion is provided by the propellers mounted on the Hovercraft. The airs from the propellers are passed over rudders, which are used to steer the craft similar to an aircraft. Hovercraft is thus propelled and controlled and its powerful engine makes it to fly.

MAIN PARTS

Lower hull- It is the basic structure on which the Hovercraft floats when the engine is stopped while moving over water. It supports the whole weight of the craft.

Skirts- They are air bags inflated by air are fitted around the perimeter of the craft hold air under the craft and thus upon a cushion of air. It enables to obtain greater Hover height. The material used is rib stop nylon or Terylene.

Lift fan-It is fitted to the primary structure of the Hovercraft. The air is pumped under the craft between the skirt space to produce a cushion of air.

Propeller-It is used to obtain the forward motion of the craft. It is fitted to the top of the craft and is powered by a powerful gas turbine or diesel engine.

Rudders-They are similar to that used in an aircraft. Rudders are moved by hydraulic systems. By moving the rudders we can change the direction of the craft.

DEVELOPMENT OF AIR CUSHION BY MOMENTUM CURTAIN EFFECT

Stability of the Hovercraft on its cushion of air remained a real problem despite some design efforts and new approach was needed. To solve these problems, plenum chamber with a momentum curtain was developed by Sir Christopher Cockrell.

His first experiments were conducted with the aid of two cans and a vacuum cleaner (with blower end). The cans were drilled and bolted so that one can was inside the other with open ends facing down to some weighing scales, the top of the larger can was open and had a tube connected to it so that air could be forced in to the top can and around the smaller can inside.

The air traveled around between the inside of the bigger can and outside of the smaller can and was then let out towards the scales in a narrow ring of air, the cans were mad4e so that it was possible to remove inner can so the air could be directed in two ways.

The experiment was conducted in two steps. First the smaller can was removed and blower switched on. The scales measured the amount of thrust the air from the one can produced down onto the scales. The smaller can was now replaced inside the larger can so that the ring of air was produced. Again the blower was switched on and the scales measured amount of thrust the ring of air produced down onto the scales. Here is the key discovery because Cockrell observed that the two cans nested inside each other produced more thrust onto the scales than the simple open can or plenum chamber did, he had discovered the momentum curtain effect and this was the key ingredient that he patented.

In the full size craft the plenum chamber was also filled in so that a slot round the bottom edge of plenum chamber wall was former where the air fed in at the top. The slot produced a curtain of flowing air that was inclined. The high pressure air from the slot angled inwards towards the centre of the craft helped to contains and sustains the air cushion. Using this method a stable air cushion could be created. The craft was still riding on a plenum chamber of sorts but it was created and maintained by the high pressure ring of air surrounding the lower pressure air in the center.The momentum curtain arrangement achieved higher hover heights with less power. It also solved some of the stability problems. The box structure in the center of the craft around which air escaped was closed to form a buoyancy tank to enable the craft to float on water when it came to rest.

The design was exactly what was used in first publicly demonstrated Hovercraft the SRN1, built by Saunders Roe in the United Kingdom it served as a test bed for many years during Hovercraft development.

HOVERCRAFT SKIRTS

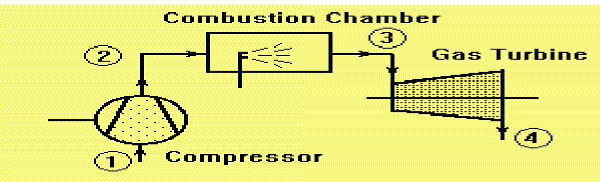
Despite the momentum curtain being very effective the hover height was still too low unless great, and uneconomical, power was used. Simple obstacles such as small waves, or tide-formed ridges of shingle on a beach, could prove to be too much for the hover height of the craft. These problems led to the development of the skirt

A skirt is a flexible shaped strip fitted below the bottom edges of the plenum chamber slot. As the Hovercraft lifts, the skirt extends below it to retain much deeper cushion of air. The development of skirts enables a Hovercraft to maintain its normal operating speed through large waves and also allows it to pass over rocks, ridges and gullies.

Skirt is one of the most design sensitive parts. The design must be just right or an uncomfortable ride for passengers or damage to craft and skirts results. The skirt material has to be light flexible and durable all at the same time. For skirt to meet all of the requirements the design and use of new materials has slowly evolved.

There are three types of skirts

- Bag skirt
- Finger skirt



The engine has a main shaft on which is mounted a compressor and turbine. A starter motor is connected to one end and the other end is connected to the lift fan. Both the compressor and turbine look like fans with large number of blades. When the engine is started the compressor compresses air from the engine intakes and pushes into the combustion chambers mounted around the engine. Fuel is squirted into the combustion chamber and is ignited. The compressed air then rapidly expands as it is heated and forces its way out through the turbine to the exhaust. As the gas pressure raises the turbine speeds up, there by driving the compressor faster. The engine speed increases until it reaches engines normal operating speed. However the use of these engines results in very high level of engine noise outside the craft. In the SRN6 this meant that it was possible to hear the craft traveling across the Solent between the Portsmouth and the isle of Wight in the UK several miles away. The current AP188 crafts that runs on the old SRN6 routes has now moved back towards the piston engines and uses marine diesel engines that are much quieter and fuel efficient.

LITERATURE REVIEW

In the beginning Hovercraft as we know them today started life as an experimental design to reduce the drag that was placed on boats and ships as they ploughed through water. The first recorded design for an air cushion vehicle was put forwarded by Swedish designer and philosopher Emmanuel Swedenborg in 1716. The craft resembled an upturned dinghy with a cockpit in the centre. Apertures on either side of this allowed the operator to raise or lower a pair of oar-like air scoops, which on downward strokes would force compressed air beneath the hull, thus raising it above the surface. The project was short-lived because it was never built, for soon Swedenborg soon realized that to operate such a machine required a source of energy far greater than that could be supplied by single human equipment. Not until the early20th century was a Hovercraft practically possible, because only the internal combustion engine had the very high power to weight ratio suitable for Hover flight. In the mid 1950s Christopher Cockrell, a brilliant British radio engineer and French engineer John Bertin, worked along with similar line of research, although they used different approaches to the problem of maintaining the air cushion. Cockrell while running a small boatyard in Norfolk Boards in the early 1950s began by exploring the use of air lubrication to reduce the hydrodynamic drag, first by employing a punt, then a 20 knot ex-naval launch as a test craft.

DESIGN AND MODELLING

CATIA (Computer Aided Three-dimensional Interactive Application) (in English usually pronounced is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systèmes directed by Bernard Charlès.Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systèmes software suite.

CATIA enables the creation of 3D parts, from 3D sketches, sheetmetal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die.

DESIGN

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse.

SYSTEMS ENGINEERING

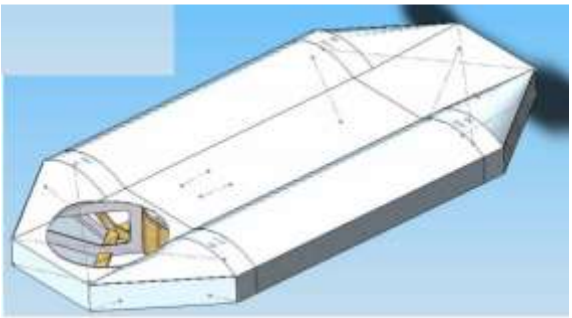
The CATIA Systems Engineering solution delivers a unique open and extensible systems engineering development platform that fully integrates the cross-discipline modeling, simulation, verification and business process support needed for developing complex 'cyber-physical' products. It enables organizations to evaluate requests for changes or develop new products or system variants utilizing a unified performance based systems engineering approach. The solution addresses the Model Based Systems Engineering (MBSE) needs of users developing today's smart products and systems and comprises the following elements: Requirements Engineering, Systems Architecture Modeling, Systems Behavior Modeling & Simulation, Configuration Management & Lifecycle Traceability, Automotive Embedded Systems Development (AUTOSAR Builder) and Industrial Automation Systems Development (ControlBuild).

CATIA uses the open Modelica language in both CATIA Dynamic Behavior Modeling and Dymola, to quickly and easily model and simulate the behavior of complex systems that span multiple engineering disciplines. CATIA

& Dymola are further extended by through the availability of a number of industry and domain specific Modelica libraries that enable user to model and simulate a wide range of complex systems – ranging from automotive vehicle dynamics through to aircraft flight dynamics.

Electrical Systems

CATIA offers a solution to facilitate the design and manufacturing of electrical systems spanning the complete process from conceptual design through to manufacturing. Capabilities include requirements capture, electrical schematic definition, interactive 3D routing of both wire harnesses and industrial cable solutions through to the production of detailed manufacturing documents including formboards.



RESULTS AND DISCUSSIONS

The finite element method is a powerful tool to obtain the numerical solution of wide range of engineering problem. The method is general enough to handle any complex shape or geometry, for any material under different boundary and loading conditions. The generality of the finite element method fits the analysis requirement of today‟s complex engineering systems and designs where closed form solutions of governing equilibrium equations are usually not available. In addition, it is an efficient design tool by which designers can perform parametric design studies by considering various design cases, (different shapes, materials, loads, etc.) and analyze them to choose the optimum design. The method originated in the aerospace industry as a tool to study stress in a complex airframe structures. It grows out of what was called the matrix analysis method used in aircraft design. The method has gained increased popularity among both researchers and practitioners. The basic concept of finite element method is that a body or structure may be divided into small elements of finite dimensions called "finite elements". The original body or the structure is then considered, as an assemblage of these elements connected at a finite number of joints called nodes or nodal points.

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The ANSYS computer software is a large-scale multi purpose finite element program that may be used for solving several classes of engineering problems. The analysis capabilities of ANSYS include the ability to solve static and dynamic structural analyses, steady state and transient problems, mode frequency and buckling eigen value problems, static or time varying magnetic analyses and various types of field and coupled field applications. The program contains many special features which allow non-linearties or secondary effects to be included in the solution such as, plasticity, large strain, hyper elasticity, creep, swelling, large deflections, contact, stress, stiffening temperature dependency, material anisotropy and radiation. As ANSYS was developed. Other special capabilities such as, sub structuring, sub modeling, random vibration, kinetostatics, kinetodynamics, free convection fluid analysis, acoustics, magnetic, piezo-electrics, coupled field analysis and design optimization was added to the program. These capabilities contribute further to make ANSYS a multi purpose analysis tool for varied engineering disciplines.

The ANSYS program has been in commercial use since 1970 and has been used extensively in the aerospace, automotive, construction, electronics, energy services, manufacturing, nuclear plastics, oil and steel industries. In addition, many consulting firms and hundreds of universities use ANSYS for analysis, research and educational use.

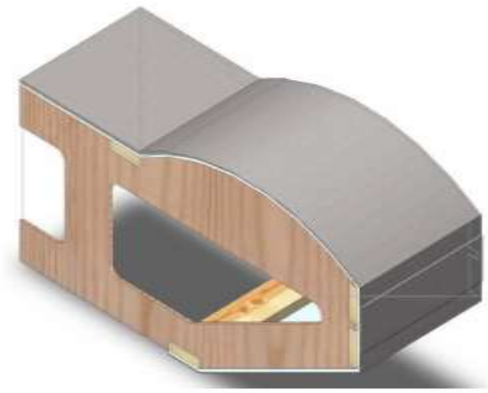
Modal analysis

The modal analysis is to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It also can be a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis. I he important feature of modal analysis is modal cyclic symmetry, which allows reviewing the mode, shapes of a cyclically symmetric structure by modeling just a sector of it. Modal analysis in the ANSYS family of products is a linear analysis. Any nonlinearity, such as plasticity and contact (gap) elements, are ignored even if they are defined.

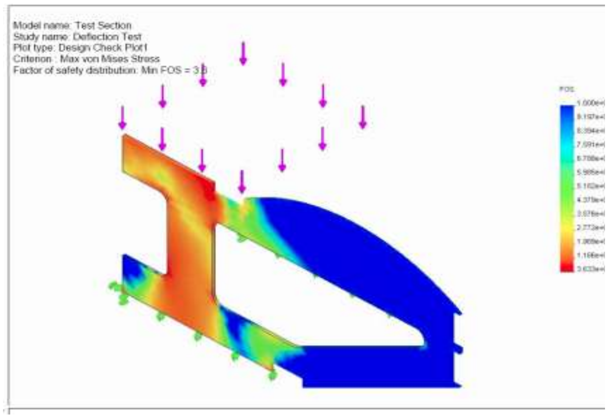
Procedure for modal analysis in ANSYS

- Create the model using linear elements because modal analysis supports linear problem only.
- Define the material properties of linear isotropic such as young's modulus and density etc.,
- Apply the loads like engine, gear box, propeller shaft for the unladen condition, and for the laden condition, including above loads, passengers and driver's weight are also applied.
- Arrest the-nodal degrees of freedom at the top and bottom nodes of the tyre in all directions and remove the constraints in vertical direction at top node of the tyres.
- Enter the ANSYS solution processor in which analysis type is taken as modal analysis, and 'by taking mode extraction method, by defining number of modes to be extracted. Solution method is chosen as Block lanczos method.
- Solve the problem using current LS command from the tool bar.

Model



Results:Factor Of Safety Along Y-Axis



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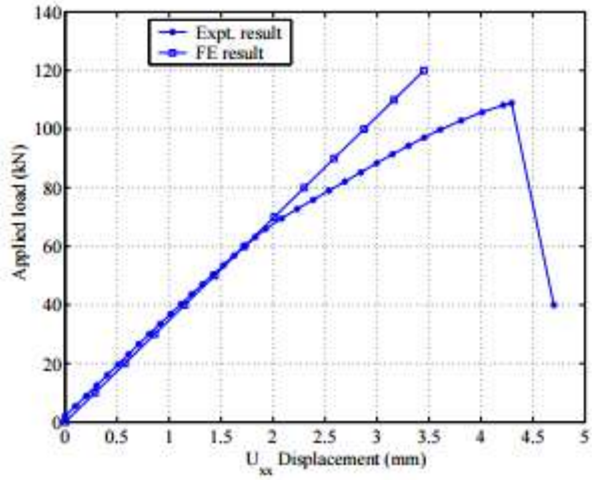
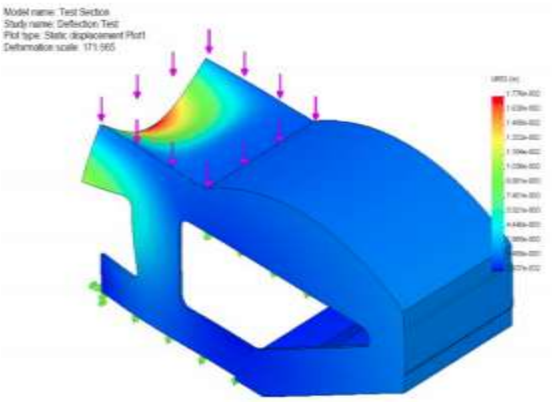
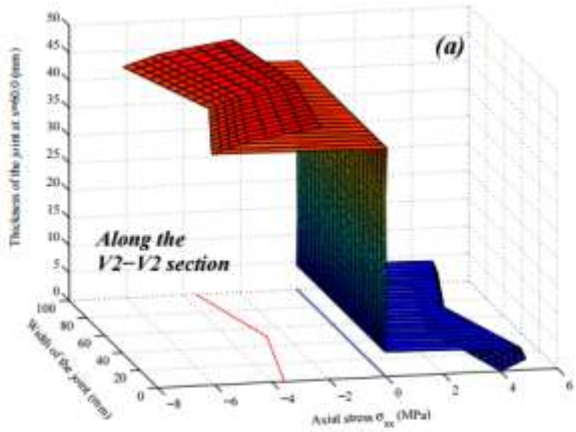
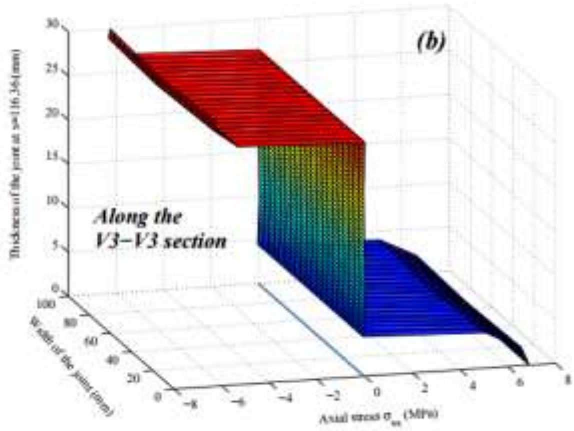
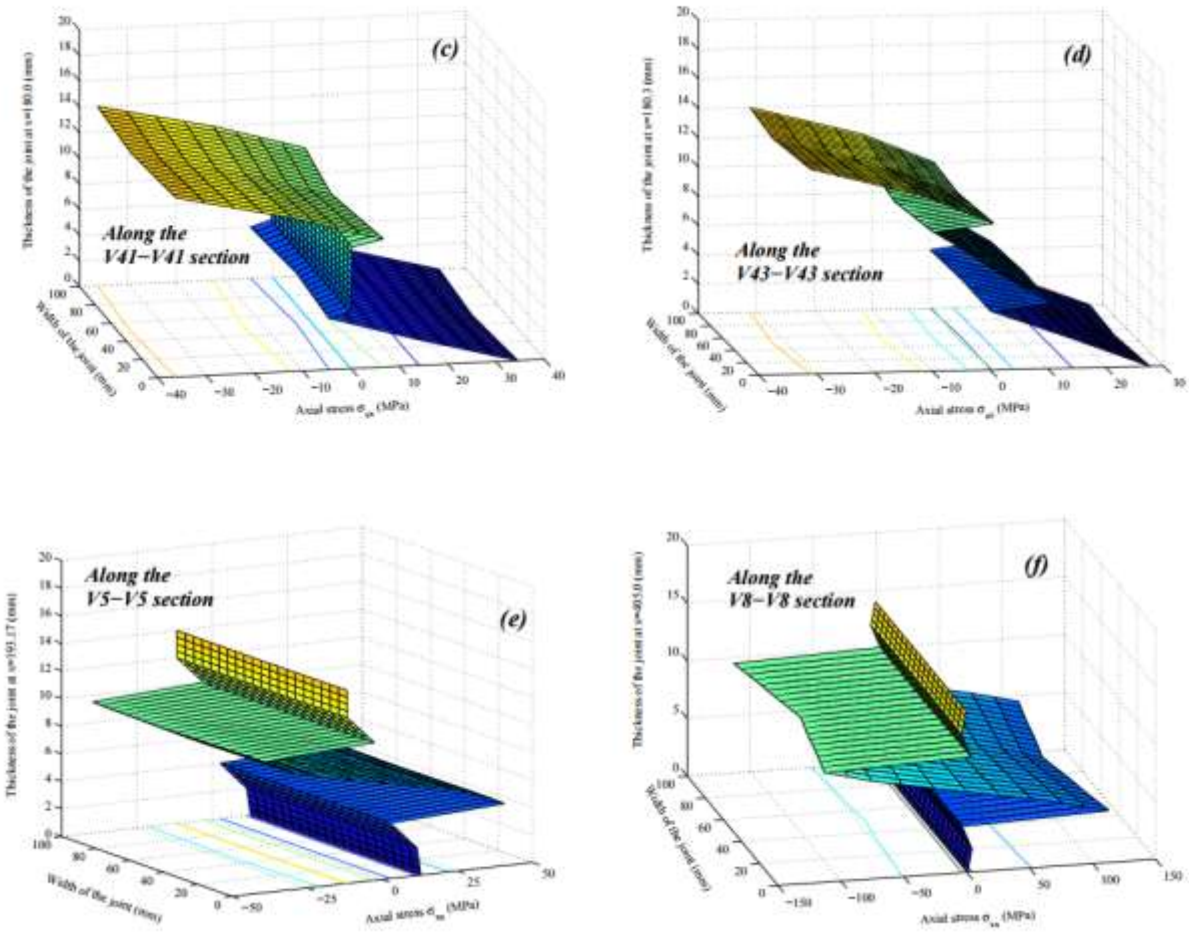


Load Vs Deflection curve for the hybrid joint under static compression load









Axial stress (σ_{xx}) along the vertical planes subjected to flexural loading (Load = 1.5 kN)

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 analyzed by using wind tunnel experiment. The lift force required to hover the craft is produced by the attached wing. In traditional model the power from single engine unit is split into two part for getting thrust and lift. In this winged hovercraft the most engine power will be delivered to propulsion alone, thus its possible to hover the vehicle at higher speed with built in lift wings. Also a Three dimensional modelling of a GRP-Steel hybrid joint that forms a structural component between the hull and the superstructure in the hovercraft is attempted for the first time in the final study. Three dimensional analysis 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.

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