## Sudan University Of Science And Technology

## CollegeOf Engineering

## School Of Mechanical Engineering

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**Aproject of:**

# DESIGN OF A TYPICAL MULTI-ROLE VEHICLE USING QUAD-ROTOR THEORY


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# Abstract

This research presents a design of a typical multi-role vehicle that can be used in the air, above the water and the ground as a typical remote controlled “RC” model. The design of the vehicle was a challenge of combining an unmanned aerial vehicle called quad-copter, with an unmanned model of a ground and marine vehicle called hovercraft.

The research approved the possibility of the combination between the two vehicles. The required calculation to reach this combination had been made into two divisions: the marine and the ground state, and the aerial state. Designing and modeling of the vehicle was conducted using CATIA, where finally a concept for the multi role vehicle has been fully defined. The research also described, in detail, the theory of control of the vehicle in the two states.

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## ملخص البحث:

البحث يصف تصميما لمركبة متعددة المهام يمكنها ان تستخدم برا وبحرا وجوا كنموذج مصغر يتم التحكم به عن بعد بواسطة جهاز ارسال يتحكم به المستخدم، تصميم المركبة مثل تحديا في كيفية دمج مركبتين مختلفتين، احداهما مركبة جوية موجهة عن بعد تسمي Quad-copter والاخري نموذج لمركبة برية بحرية تسمي، Hovercraft .

البحث تم بواسطته اثبات إمكانية دمج المركبتين سابقتي الذكر للحصول علي المركبة المنشودة؛ وللوصول لهذا الهدف، تم اجراء الحسابات اللازمة لاجراء هذا الدمج بين المركبتين اخذين في الاعتبار الحالتين التي تم تصميم المركبة علي اساسهما: وهما الحالة البرية البحرية "البرمائية" والحالة الجوية، عملية تصميم المركبة تمت بواسطة برنامج كاتيا "Catia"، حيث تم تعريف كامل لتصور المركبة متعددة المهام. البحث ايضا تم فيه وصف كيفية التحكم بالمركبة في حالتيها الاثنتين.

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## List of symbols:

| | |
|---|---|
| $w$ | Width of the vehicle |
| $l$ | length of the vehicle |
| $P_{cu}$ | Cushion pressure |
| $W$ | Total weight of the vehicle |
| $A_{cu}$ | Cushion area |
| $P_{bag}$ | Bag pressure |
| $h_{skirt}$ | Skirt height |
| $V_c$ | Velocity of air |
| $\rho$ | Mass density of air |
| $Q$ | Total volume of air |

| | |
|---|---|
| $h$ | Clearance height of the ground |
| $I_{cu}$ | Perimeter of the air cushion |
| $D_c$ | Discharge coefficient |
| $Q^*$ | Total mass flow |
| $C$ | Flow loss factor |
| $A_{holes}$ | Total area of the peripheral jets holes |
| $P$ | The power required to sustain air cushion |
| $TH$ | Thrust of the quad-copter |
| $F_1, F_2, F_3, F_4$ | Forces generated by motors 1,2,3,4 |
| $m$ | Weight of the vehicle |
| $g$ | Gravity |
| $P$ | The required hovering power |
| $V_i$ | The induced velocity of the vehicle |
| $A$ | The area of the rotor |
| $m$ | Mass of the vehicle |
| $\dot{u}$ | Acceleration on x axes |
| $v$ | Velocity on y axes |
| $r$ | Angular velocity yawing |
| W | Velocity on Z axes |
| $q$ | Angular velocity on pitching |
| $X$ | X axes |
| $p$ | Angular velocity on rolling |

| | |
|---|---|
| $u$ | Velocity on X axes |
| $Y$ | Y axes |
| $\dot{w}$ | Acceleration on Z axes |
| $Z$ | Z axes |
| $I_x$ | inertia around X axes |
| $I_z$ | inertia around Z axes |
| $I_y$ | inertia around Y axes |
| $\dot{r}$ | Acceleration on Z axes |
| $I_{xz}$ | The product of inertia on XZ coordinates |
| $I_{yz}$ | The product of inertia on YZ coordinates |
| $\dot{q}$ | Angular acceleration on pitching |
| $I_{xy}$ | The product of inertia on XY coordinates |
| $K$ | Forces on rolling |
| $I_{zx}$ | The product of inertia on ZX coordinates |
| $M$ | Forces on pitching |
| $N$ | Forces on yawing |
| $\dot{z}_1, \dot{z}_2, \dot{z}_3$ | Velocities of the three States of transforming to earth-fixed coordinate system |
| $\dot{v}$ | Acceleration on Y axes |
| $z_1$,$z_2$,$z_3$ | three states are added to go from velocities to positions in the earth-fixed coordinate system |

| | |
|---|---|
| $d_{11},d_{22},d_{33}$ | Damping coefficients |
| $F_{w1},F_{w2},F_{w3}$ | Friction forces |
| $J_z$ | moment of inertia on Z axes |
| $F_{xx}$ | the back thrust |
| $a$ | The length of the arm of the force causing a moment around the z-axis |
| $\delta$ | the back thrust angel |
| $V_d$ | the discharge velocity |
| $A_f$ | the fan area |
| $V_o$ | the free stream velocity |
| $D$ | Direction cosine matrix |
| $\dot{x},\dot{y},\dot{z}$ | the change of position according to quadrotor's attitude |
| $\dot{\phi}$ | Roll angel |
| $\dot{\theta}$ | Pitch angel |
| $\dot{\psi}$ | Yaw angel |
| $F_x$ | Forces acting on X axes |
| $F_y$ | Forces acting on Y axes |
| $F_z$ | Forces acting on Z axes |
| $W_x$ | Weight acting on X axes |
| $W_y$ | Weight acting on Y axes |
| $W_z$ | Weight acting on Z axes |
| $b$ | Thrust constant |

| | |
|---|---|
| $\Omega_1$ | Angular velocity of first motor propeller |
| $\Omega_2$ | Angular velocity of second motor propeller |
| $\Omega_3$ | Angular velocity of third motor propeller |
| $\Omega_4$ | Angular velocity of fourth motor propeller |
| $M_x$ | The external torque on X axes |
| $M_y$ | The external torque on Y axes |
| $M_z$ | The external torque on Z axes |
| $d$ | drag factor |

# Chapter One

# Introduction

## 1.1 Introduction:

The world is looking for the most helpful things and tools in humans' life. One of these things isvehicles. Duringdifferenteras the human tried to develop vehicles. Among these, recently human developed unmanned or remotely controlled vehicles for various applications to meet different needs.

This project aims to design a multi-role vehicle which can be used in the ground, in the water and in the air at the same time. The design aims to combine an unmanned marine & ground vehicle which is called a hovercraft, with an unmanned version called the quad-copter.This kind of vehicles hasn't commonly been used in the world in a formal way till now.

Thescope is that, the design of the vehicle isonly conceptual and typical one with a character that can be magnified to work as a manned vehicle.

The project study will generally be considered from two main design view-points:

1. Designing of unmanned marine & ground vehicle "hovercraft", and
2. Designing of unmanned aerial vehicle"quad-copter".

The theories of unmanned vehicles, air-cushion vehiclesand vertical takeoff and landing vehicles, represents the scientific background for this project, which are combined together and appliedto the vehicle so as to achieve themulti-role design.

## 1.2 Research problem:

The research problem is addressedby answering the following questions:

1- Can the human use one vehicle in the threeambiences, the ground, the water and the air?
2- How to make a new combination between the three types of vehicles into one vehicle which can perform in the three ambiences effectively?

### 1.2.1 Research importance:

The technology challenge nowadaysis to find the mosthelpful, modern and easy ways for the human kind use. Vehicles are one of those things that play a great role to help human kind in many purposes.

The research is seeking to make new generation of vehicles that can have a multi-role by working in the three different environments: ground, water, and air simultaneously.

## 1.3 Research objectives:

1- Generalobjective:The general objective is to make a conceptual design of a multi-role vehicle which can work in the ground, the water and air.
2- Specific objectives: the specific objectives are:
   a- Conducting a conceptual design of an unmanned hovercraft system.
   b- Conducting a conceptual design of an unmanned quad-copter systemthat works up to the range of 500 meters above the ground.
   c- Combining the two systems in one vehicle.

## 1.4 Scope of the research:

The main basis of the research is the vertical takeoff and landing and the air-cushion vehicles in the form of an unmanned vehicle. The scope of the research is to design the vehicle in two parts:as a ground vehicle; and then as a marine and air

vehicle state. That should be conducted by gathering the required data& calculations of the both states.

Modeling of the vehicle is the next step by using computer software and making the required tests and trying to find a suitable design which gives the vehicle the ability of working in the air, the ground and the water.

## 1.6 Research proposed plan:

### 1.6.1 Gantt chart:

The research Gantt chart shown in Table (1.1):

## Table (1.1) Gantt chart