DESIGN, ANALYSIS AND FABRICATION OF OBSTACLE AVOIDING HOVERCRAFT

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Abstract

Hovercrafts are categorized under Air Cushioned Vehicle which can travel on land, water, snow, mud, grass, sand, etc. This hovercraft uses a layer of air cushion under the craft to hover on the surface smoothly i.e. no actual contact between base of the hovercraft and surface on which it is hovering. The propeller pushes the craft to make the hovercraft movement. In this project, auto obstacle avoidance mechanism have been provided in the hovercraft by considering the factors such as size, materials used for skirt, weight carrying capacity, speed and strength required by the hull. In this paper, various design parameters have been studied and analyzed in Ansys to enhance the performance characteristics of hovercraft.

Keywords: Hovercraft; obstacle avoidance, Ansys.

1. Introduction

A hovercraft is a type of transportation vehicle categorized under air-cushion vehicle. These vehicles created a layer of air between the vehicle and the surface of travel, thus the air layer act as the cushion and reduce the friction. So the vehicle is independent upon the surface and can travel over land, water, mud, ice, etc. The speed of the vehicle is high because of the less friction. Both at dynamic and stationary conditions, a layer of air have been continuously forced under the vehicle by a fan with high speed, generating the cushion layer that greatly reduces friction between the moving vehicle and surface. Emanuel Swedenborg, Swedish designer introduced the idea of hovercraft and Sir John Thorneycroft experimented the idea of air lubrication on boats to reduce drag. In 1876, John B. Ward designed hovercraft with aluminum platform. In 1888 James Walker developed a system of containing the air under the platform and in 1897 Culbertson made the suggestion for sidewall air-cushion vehicles. The movement of the hovercraft depends by controlling the lift, thrust, and steering systems. As the air cushion reduces the friction and thereby the speed increases. On the other hand, the steering became a crucial part of the hovercraft. Again the obstacles on the path will make the hovercraft to steer continuously, which will be fatigue task forth hover pilot. Even though the hovercrafts have been design to pass over the obstacles, its strength get reduced and the vibration generated to the passengers. So a necessity arises to avoid the obstacles by automatically detecting them and also need arises for the intelligent system to take decision to avoid the obstacle or to pass over the obstacle. In this work, in order to overcome the challenges, array of ultra-sonic sensors and the controller have been used.

Amiruddin et al provided the detailed information about the construction and working of the hovercraft along with the mechanism of lifting fan, thrust propeller, hovercraft skirt, air

box, lift system, thrust system, steering system. Okafor et al has given the design calculations of hull, lift system, skirt and thrust system. Okiishi et al mentioned information about the fabrication of the hull, air box, skirt and engine. Amyot explained the technologies and the application of the hovercraft. Doctors concentrated and derived equations for non linear motion of air cushion vehicles when the vehicle passed over the sea shore waves.

2. Developed Hovercraft

The developed hovercraft prototype can carry the weight of 100 kg and hovered with an air cushion of 1.5 centimeters. Entire model build with low cost materials and analyzed for the performance theoretically. Separate propeller with three blades has been used for the propulsion and for lifting systems, holes are provided on the skirt, which will pressurize the air at high pressure and thereby creates the lift. In order to create the pressure inside the skirt, the air is continuously blow into the skirt with high pressure, then the air is allowed to circulate in the skirt, also the air is allowed to get out on the small hole outlet which create the pressure between the earth surface and the craft, thus the impact create the lift and also reduce the friction between the earth surface and the craft. This frictionless air cushion makes the craft to run on the surface freely at higher speed. Also the air cushion makes the movement independent of the surface. The developed hovercraft prototype is having aluminum hull base. Because the aluminum alloys are more economical and robust. Further, structural analyses by using ANSYS software have also conducted to validate the suitability and reliability of the hull base. After series of experimental testing and upgradations, propulsion and lifting systems were successfully demonstrated.

By mounting the rudders adjacent to the propeller along the airflow direction helps in the hovercraft steering. These rudders are controlled by the driver motors which inturn control by the circuit boards and the controllers. By shifting the steering wheel, the rotary potentiometer connected to the steering wheel emits the emf based on the angle of rotation. This emf have been amplified and given to the controller. Based on the pulse, the controller emits the signal to the relay and the relay in turn gives power to the driver and the motor connected to the rudders. Thus the rudders turn and thereby change the direction of the airflow. i.e. change in direction of the rudders changes the direction of air flow which causes change in direction of the hovercraft. Thus the hovercraft becoming popular and easy to drive at the higher speed. On the other hand, when the craft is moving at the higher speed and there is no friction exist between the vehicle and the surface, will lead to challenges like loss of control by the pilot, rollout when hits over the obstacle, lifting of the craft when moves over the obstacles, formulation of horizontal moment on the craft and make the craft rotate with respect to the axis, etc. Moreover it became difficult for the driver to turn the vehicle by observing the obstacles immediately. So a necessity arises to develop an automatic obstacle avoidance system for the hovercraft.

So to overcome the challenges, in this project, eight numbers of ultrasonic sensors have been used. These sensors are triggered every 3 seconds simultaneously. The trigger signals for the ultrasonic sensors are provided by the Arduino controller. The trigger pins of the ultrasonic sensors are connected in serious. When the controller emits the trigger signal, in turn the ultrasonic sensor emits the ultrasonic waves. The ranges of the waves are for about 3 meter distance and the waves reflected if there are any obstacles and returned back to the

receiver of the ultrasonic sensors. These receiver pin of the ultrasonic sensors are connected separately to the eight input pins of the Arduino board. The difference between the time of trigger and the receiving of the signals is proportional to the distance of the obstacle and the craft. Thus the distance of the obstacles is shown in the dashboard of the pilot with a warning beep sound. The intensity of the beep depends on the size of the obstacles. If all the eight sensors emits the receiver emf, then the intensity of the beeper is to the maximum and for the 4 sensors output, it will be 50 % of its intensity and proportionally the intensity varies with respect to the output from the sensors. Similarly the distance of the object may also vary from sensor to sensor based on the shape and size of the obstacle. For the arbitrary shaped obstacles will vary in the distance from the sensor to the sensor. So in this project the Arduino have been programmed to show the minimum distance to the pilot dashboard. An expert system module have been developed to control the speed of the hovercraft. If all the eight sensors emits the signal, immediately the controller send the negative feedback signal to the propeller motor controller and the propeller motor controller reduces the speed of the propeller to the 50 % of the current speed automatically for 3 seconds. Within 3 seconds, iof the pilot hold the accelerator to the same speed ort increase the accelerator, the module resets and move with the defined speed. Else if the pilot releases the accelerator or reduces the speed slowly, then the obstacle avoidance expert system activates.

The obstacle avoidance expert system having the predefined cases and the solutions programmed in the controller memory. When the system activates, it helps the vehicle to avoid the obstacles by slightly turning the craft and by providing the higher pressure near the obstacle crossing edges. The controller is having 4 input pins and the each pin is connected the two sensors in sequence. Sensor arrangement is shown in the Figure 1.

Figure 1 Sensor Arrangement

Thus the developed model turns accordingly based on the position of the obstacles. Also the higher pressure of air supplied to the holes in the skirt. This pressurized air lifts the craft to another 1.5 centimeters. Thus the height helps the craft to easily move over the obstacles. Also the pressure of air increases the cushioning effect and thereby prevents the vehicle from the damages and the scratches.

3. Result and Discussion

The developed hovercraft moves over the air and independent over the surface. Also the expert system in the craft avoids the obstacles by turning the craft to the acceptable angle turnings and also increases the pressure of the obstacles side and thereby increases the cushioning for the vehicles. Thus the developed vehicles can run on sand, asphalt, water, snow, mud, etc. Various experiments have been conducted with the different surfaces and the obstacles. The results of the experiments have been investigated and found that the turning at the higher speed will affects the dynamics of the vehicle, so the relation equation have been framed to reduce the speed of the vehicle with respect to the angle of turning. Thereby the dynamics of the hovercraft have been maintained. The Equation used to calculate the lift force are given in the Equation 1.

$$Fc = W = PxA + J_j L_j \, Sin \, \theta_j \quad (1)$$

Where as, P and A denotes the pressure and Area of cushion, J denotes the momentum flux and θj denotes the angle of the nozzle (45 degrees).

The total volume flow of the skrit is calculated from the Equation 2.

$$Q_j = \frac{L\,H}{1+cos\emptyset} \times \sqrt{\frac{2P}{\rho}} \times (1 - \sqrt{\frac{Pc}{Pj}}) \quad (2)$$

The hovercraft has been developed with an aluminum composite panel, because of the low weight, less cost, readily available, easy to machine and high strength to weight ratio. In this study, strength of the aluminum plate have been analyzed for the adoptability for the hovercraft. The hull base is drafted in CATIA software and imported to ANSYS software for analysis. This software can be applied for 3 dimensional analyses of the modelling. The length is set to 250 centimeters, breadth of 150 centimeters. The weight to be lifted 100 kgs, force required to move the vehicle is 1200 N. Pressure required to lift the hovercraft is 32 N/m^2. Efficiency of blower $\dot{\eta}$ = 0.7 and able to generate 10 KN/m^2 pressure. With the acceleration of 0.8925 m/s2, it is possible to achieve 40 km/hr. density of the base plate is 1600 kg/m^3, Ultimate Tensile strength = 48.7 MPa , Yield strength = 46.4 MPa. The load act on the plate is 1200 N and the front and back side having 20% increase in the load. From above analysis, it is clear that the maximum stress developed is 46.232 MPa, which is in the safe limit only. The maximum deformation is 1.4 mm. the Ansys analysis of stress distribution is shown in the Figure 2.

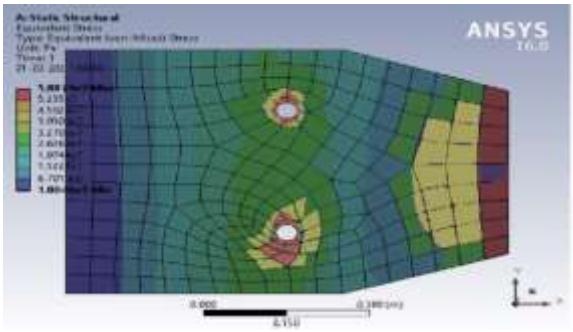

Figure 2 Ansys Analysis – Stress Distribution

4. CONCLUSION

In this investigation, a hovercraft have been designed and developed to lift the load of 100 kg. The hovercraft has been fitted with the ultrasonic sensors and these sensors used to avoid the obstacles in the path of the hovercraft movement. The expert system developed will guide the hovercraft by considering the dynamics of the vehicle. Also the system reduces the speed intelligently. The ANSYS results shows that the developed hovercraft is safe and can be used for the applications.

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