



DESIGN AND FABRICATION OF UNMANNED VEHICLE

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Abstract:

Unmanned vehicle is a vehicle that operates without any on board presence of human and operated by a remote guidance. The unmanned vehicles are constructed as a solution where the human presence is riskier such as military operations, nuclear facilities. The various problems in constructing an unmanned vehicle are safety, collision avoidance and controlling. The goal of this project is to design and fabricate an unmanned vehicle which can be operated by a remote guidance and lifts itself by propellers fixed to it. The design phase of this project involves designing the components such as battery power capacity, transmission system for ground movement and the extension arm mechanism for lifting. The unmanned vehicle is accompanied with the microprocessors, sensors and switches for controlling the forward and reverse motion operations. An extension arm is fixed for the propeller which the arm is extended and retracted by a rack and pinion gear mechanism and control switches. The modeling of unmanned vehicle is made using the CATIAv5 software. The final procedure in this project involves fabricating an unmanned ground vehicle for the designed specifications

Index Terms: Unmanned Ground Vehicles, Lifting Arm Mechanism & CAD Model Using CATIA

1. Introduction:

Unmanned vehicles are capable of running with the help of a remotely guided operator. Unmanned vehicles can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. Generally, the vehicle will have a set of sensors to observe the environment, and will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle. The unmanned vehicle is the land-based counterpart to unmanned aerial vehicles and remotely operated underwater vehicles. Unmanned robotics is being actively developed for both civilian and military use to perform a variety of dull, dirty, and dangerous activities. Unmanned vehicles can be operated either by having an electrical motor or an internal combustion engine as power source for operation.

There are a wide variety of remote-operated unmanned vehicles in use today. Predominantly these vehicles are used to replace humans in hazardous situations. Examples are explosives and bomb disabling vehicles. According to Carafano & Gudgel, robots have disarmed over 1000 roadside bombs in Iraq at the end of 2005. Currently, unmanned vehicles are also being used in Japan repairing nuclear reactors that are still emitting too much radiation to warrant a human presence.

Unmanned vehicles are also being developed for peacekeeping operations, ground surveillance, gatekeeper/checkpoint operations, urban street presence, and to enhance police and military raids in urban settings. Unmanned vehicles can "draw first fire" from insurgents - reducing military and police casualties. Furthermore, unmanned vehicles are now being used in rescue and recovery missions.

2. Related Works:

Recent developments in technologies for sensing and control of autonomous ground vehicle have demonstrated the ability to accurately determine the position and velocity information, thereby leading to better performance of unmanned vehicles. In 1994, Takashi Gomi, Kooichi Ide and Hirokuzu demonstrated the technique employed in non-cartesian way of organizing software agents for creating control programs. Saurav Chakraborty, Subhadip Basuet al discussed on designing a smart Unmanned Vehicle which is designed and developed for some application specific missions to operate predominantly in hazardous environments. In their work, they have developed a small and lightweight vehicle to operate in general cross country terrains in or without daylight. The unmanned vehicle can send visual feedbacks to the operator at a remote location. On-board infrared sensors can detect the obstacles around the unmanned vehicle and sends signals to the operator. The present work draws from these articles and extends scope to design, analysis and testing of an unmanned vehicle which can lift itself by the help of an lifting arm provided with thrust motor and propellers.

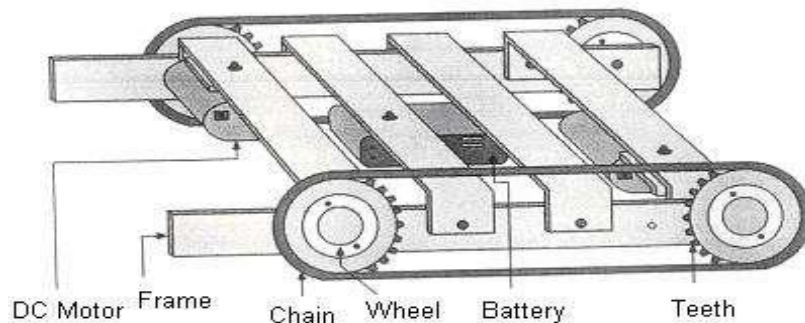


Figure 1: Mechanical structure of unmanned vehicle

3. Design of the Unmanned Vehicle:

An unmanned vehicle would have to be capable of working on its own or based on the commands given to it remotely in any environment. However, the major problem in operating a unmanned vehicle are reliability and failures due to control system, power, communication. The data transfer for the motion and operation of the unmanned vehicles with the remote operator is the major problem where the communication signal weakens. Another problem in the operation of unmanned vehicles is safety in urban environments.

In the proposed unmanned vehicle a lifting mechanism is introduced for keeping the vehicle stay afloat. The practical difficulties in designing such a system are weight, and space restrictions. Also it needs a separate hydraulic actuation system for extension and retraction of the side wing arm for fixing the propeller.

The various components present in the unmanned vehicle are Base frame , Electric Motor, Electric battery, Actuator, Microprocessor, sensors, Propeller Blades.

- ✓ Power Supply: the power is obtained from a 12V power supply lithium polymer battery with 20c rating which gives current of 5000milli amps. This gives supply to all circuit board either 12v or 5v as required.
- ✓ DC Motor Unit: The unmanned vehicle consists of two brushless DC motor for ground movement which get its power supply from the electric battery. Directions of these motors are controlled by the supply voltage received from relay which is controlled by control signals received from motor driver unit.
- ✓ Lifting Arm Mechanism: The lifting arm mechanism consists of a rack and a pinion system where the pinion is made to run by an electric motor. The one end of the rack is fixed with the side frames which carries the thrust motors. The side

frames extends and retracts every time the rack and pinion is operated. A side frame is attached to the end of the rack where the thrust motors are fixed to the ends of the frame.

- ✓ Base Frame: The base frame material is selected as aluminium or mild steel. The frame is made with space for attaching the battery and the electric motors. The wheels are also attached to the base frame along with the electric motors. The aluminium is selected as the suitable material for the base frame of the unmanned vehicle because of its low weight and higher strength.
- ✓ Microprocessor: It is programmed to control the speed of motor by input from the motion sensor to turn the vehicle. It processes the input signals given by the remote user and sends output to the motors for the motion control of the unmanned vehicle. The microprocessor is a multipurpose, programmable device that accepts digital data as input, processes it according to instructions stored in its memory, and provides results as output. Microprocessors contain both combinational logic and sequential digital logic and they operate on numbers and symbols represented in the binary numeral system. A typical kk2 circuit board is used here for controlling the flying operations.

3.1 Aluminium Frame:

The aluminium frame supports the lifting arm mechanism and electric actuator (motors) and fixed with the wheels at the base of it. The aluminium frame of dimensions 30*22*7 cm size is chosen and weight is found as below

Size of frame	= 30* 22* 7 cm
Density of aluminium	= 2.8 g/cm ³
The volume of the frame	= 1410 cm ³
The weight can be found as	density = mass/volume
	Mass = density * volume
	= 2.8* 1410

So the mass of the aluminium frame is 0.4 kg.

3.2 Frames Supporting the Motors:

The extension arm is fixed with the side frames made of aluminium of rectangular cross section. These side frames supports the thrust motors. The size of the supporting frame can be written as 41*1.5*1.5 mm.

Size of the frames	= 41*1.5*1.5 cm
Volume	= 92.25 cm ³
The mass of the side frame	= 2.8 * 92.25
	= 0.260 kg

Two side frames are used on the two sides of the central frame

So the total mass of the side frames are 0.52 kg.

3.3 Mass of the Battery:

The batteries are used as the power source for the ground movement and the extension mechanism and lifting operation. Here lithium polymer battery of power capacity 5000 mah has been used as the power source. The battery has the specifications of 16*7*7 cm. The mass of the battery given is 0.270 kg.

3.4 Electric Motor:

Electric motors of high torque capacity of range 7 kg-cm has been used to actuate the extension arm mechanism which comprises of a rack and a pinion system. The mass of the motor is 40 gm. The wheel motors used for ground movement has a mass of 50 gm. The mass of all the motors are found as 0.15 kg. In addition to these motors thrust

motors are fixed on the side frames. the mass of the thrust motors are 0.120 kg. So the total mass of all the motors are found as 0.27 kg.

3.5 Rack and Pinion Mechanism:

The rack and pinion mechanisms are chosen to be made of the acrylic material (polymer) so that weight reduction can be achieved. The mass of the rack and pinion system was found to be 0.30 kg. Though rack and pinion made up of mild steel gives enough rigidity and power transfer but considering the weight reduction polymer material is selected. The total weight of the entire system was found to be 3.8 kilogram.

3.6 Motor Selection Based On Torque

The selected motors should have a torque in order to move the unmanned vehicle of mass 5 kilograms. So the torque required from the motor can be calculated as follows. Let the wheel connected to the motor shaft has radius R_w , and force on wheel be F_w , and the radius of the axle of the wheel be R_a , and the total weight to be moved is W .

Now the torque can be calculated from the expression,

$$\begin{aligned} T &= F_A(R_w - R_a) \\ \text{The force } F_A \text{ can be found by } F_A &= (w \cdot \mu_a) / 2 \\ &= (5 \cdot 0.6) / 2 \\ F_A &= 1.5 \text{ N} \\ R_w - R_a &= 3 \text{ cm} \\ \text{Hence torque required is } T &= (5 \cdot 2) \cdot (0.6) \cdot (3) \\ &= 4.5 \end{aligned}$$

Now the torque required from the motor is calculated as 4.5 kg-cm. The motor selected has the following specifications, DC geared motor with shaft diameter of 5 mm having the size of 14* 12* 10 mm

Torque produced is 4.5kg-cm and having a speed of 80 revolutions per minute.

3.7 Side Frame Bending Analysis:

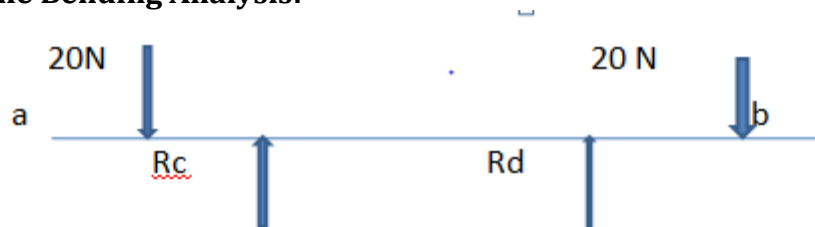


Figure 2: forces on the side frame

$$\begin{aligned} \text{Condition for equilibrium is } R_a + R_b &= 20 + 20 \text{ N} \\ &= 40 \text{ N} \end{aligned} \quad \text{----- I}$$

$$\begin{aligned} \text{Taking moments about A,} \\ (20 \cdot 330) &= (R_d \cdot 260) + (R_c \cdot 100) \\ 6600 &= 260 R_d + 100 R_c \\ 330 &= 13 R_d + 5 R_c \end{aligned} \quad \text{----- II}$$

Solving the above equations I and II

$$R_c = 23.74 \text{ N}$$

$$R_d = 16.25 \text{ N}$$

Bending moments

$$\begin{aligned} \text{About c, } M_c &= 20 \cdot 100 \\ &= 2000 \text{ N-mm} \end{aligned}$$

$$\begin{aligned} \text{Moment about d, } M_d &= 20 \cdot 70 \\ &= 1400 \text{ N-mm} \end{aligned}$$

So the maximum bending moment is 2000N-mm from the bending formula

$$\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$$

Where M = bending moment, I = moment of inertia of given section, σ = bending stress, E = youngs modulus, R = radius of curvature, $I = bh^3 / 12$

$$I = 2812.5 \text{ mm}^4$$

Finding deflection by Macaulay's method,

Taking moments about right end

$$EI \frac{d^2y}{dx^2} = (20 \cdot x) - (23.7 \cdot (x-100)) - (16.25 \cdot (x-260))$$

Integrating the above equation

$$EI \frac{dy}{dx} = 20(x^2/2) - ((23.7) \cdot (x-100)^2/2) - ((16.25) \cdot (x-260)^2/2) + A \text{-----I}$$

Again integrating the equation

$$EI y = 20x^3/6 - (23.7) \cdot (x-100)^3/6 - ((16.25) \cdot (x-260)^3/6) + Ax + b \text{-----II}$$

The boundary conditions are given as

$$\text{When } X=100, y=0$$

$$\text{And } X=260, y=0$$

Applying the boundary conditions in I and II

We get the following equations,

$$100A + B = 14.39 \cdot 10^6$$

$$260A + B = 74.78 \cdot 10^6$$

Solving the above equations, we get A and B

$$A = -37.74 \cdot 10^4$$

$$B = 23.35 \cdot 10^4$$

Deflection will be at the centre $x=160$ mm

So applying $x=160$ in eqn III we get

$$Y = 0.982 \text{ mm}$$

So the deflection of the frame is 0.982 mm.

3.8 Design of Lifting Mechanism:

The lifting mechanism which has the propeller blades fixed to the motor can be extended and retracted from the base of the unmanned vehicle frame.

The lifting arm consists of the following parts

- ✓ Rack and pinion
- ✓ Extension arm
- ✓ Propeller shaft
- ✓ Propeller motor
- ✓ Propeller blades

The working of the lifting arm involves actuation of the rack and pinion which is directly connected to the propeller shaft. The propeller shaft has an electric motor which is operated by the battery. The propeller blades rotate which give the lift force for the lift of unmanned vehicle. The working of the lifting arm fixed with the unmanned vehicle is explained by the cad model drawn by using the CATIA v5 software.

Rack : bakelite

Pinion : bakelite

Tensile stress $\sigma_u < 390 \text{ N/mm}^2$

Bending stress $\sigma_b = 560 \text{ N/mm}^2$

Calculation of Centre Distance

Corresponding Number of Starts:

$$Z = 3$$

$$Z = 1z1$$

$$24 \cdot 3 = 72$$

Check Whether Z Lies Between 25 and 85:

Choose $q = 11$

Assume $\sigma_c = 159 \text{ N/mm}^2$

Assume initially $k_d = 1$

Wheel torque = power $\times 60 \div 2 \pi \times \text{rpm of the pinion}$

$$= 50 \times 60 \div 2 \pi (50/24)$$

$$= 229 \text{ Nm}$$

$$[M_t] = k_o.k_d.M_t$$

$$= 1 \times 1 \times 229 \times 10^3$$

$$= 229 \times 10^3 \text{ Nmm}$$

$$A = [(z/q) + 1]^3 v [(540 \div (z/q) \sigma_c)]^2 [M_t] \div 10$$

$$= [(72 \div 11) + 1]^3 v [540 \div (72 \div 11) \times 159 \cdot [229 \times 10^3 \div 10]]$$

$$= 7.56 \times 18.336$$

$$= 139 \text{ mm}$$

Calculation of Axial Module"

$$M_x = 2a \div (q+z)$$

$$= 2 \times 139 \div (11+72)$$

$$= 3.3 \text{ mm}$$

Take $m_x = 5 \text{ mm}$ (standard)

$$a = 0.5 m_x (q+z)$$

$$a = 0.5 \times 5 (11+72)$$

$$= 207 \text{ mm}$$

Pitch circle diameter of rack = $d_1 = q m_x$

$$= 11 \times 5$$

$$= 55 \text{ mm}$$

V_1 = pitch line velocity of rack

$$= \pi d_1 n_1 \div (60 \times 1000)$$

$$= \pi \times 55 \times 50 \div (60 \times 1000)$$

$$= 0.1439 \text{ m/s}$$

SINCE $V_s < 4 \text{ m/s}$, the $[c]$ is Correct

REVISE k_d and $[M_t]$ for the Actual Pitch Line Velocity of the Pinion:

$$V_2 = \text{rack speed (rpm)} \times \text{lead} \div (60 \times 1000)$$

$$= 50 \times (2 \pi m_x) \text{ or } z p a \div (60 \times 1000)$$

$$= 0.03 \text{ m/s}$$

Since $V_2 = 0.03 \text{ m/s} < 3 \text{ m/s}$, $k_d = 1$

$$[M_t] = k.k_d.M_t$$

$$= 1 \times 1 \times 229 \times 10^3$$

$$= 229 \times 10^3$$

Specifications of Rack:

Material : bakelite

Module : 0.4 mm

Cross section : 15*10 mm

Number of teeth : 42

Specifications of Pinion:

Material : bakelite

Outside diameter : 40 mm

Inner diameter : 36 mm

Circular pitch : 3.3 mm

Module : 1.2 mm
 Fillet radius : 0.3 mm

4 CAD Model:

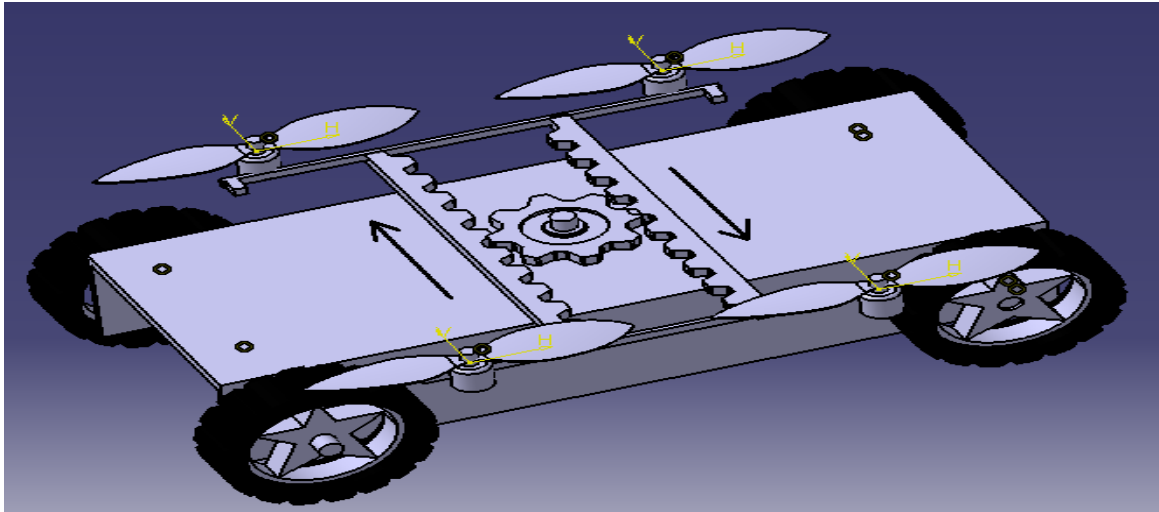


Figure 3: CAD model of proposed model with lifting arm

5. Analysis for Bending Stress:

The designed model is analysed for calculating the various forces induced in the side frame which arises due to the thrust force produced by the thrust motors during the flying operations. The thrust force has a value of 20N on each motors which can cause bending of frame. The resulting bending deflection and von misses stress are found using the ANSYS. The resulting deformed frame is given below.

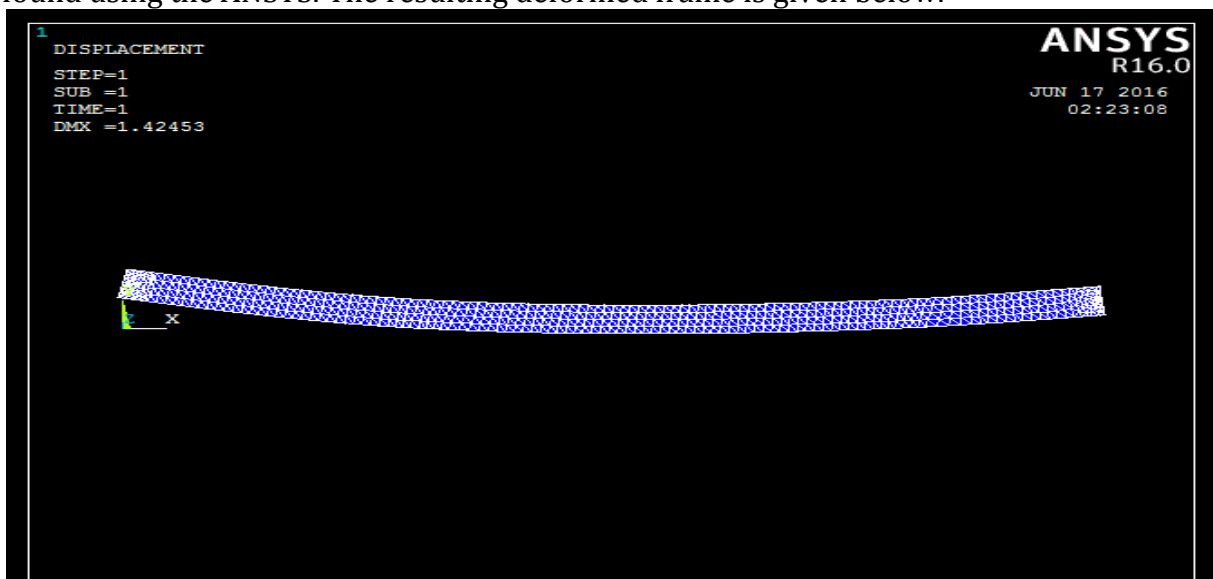


Figure 4: Deflection of the side frame

The maximum deflection found by the ansys is 1.5 mm which is safer and does not causes failure due to bending. The von misses stress value obtained is 145 N/mm². The ultimate tensile stress value for the aluminium material is found to be 370N/mm². So the stress induced in the side frame is lesser than the ultimate stress where the design is found to be safe and the induced stress doesn't causes any failure of material.

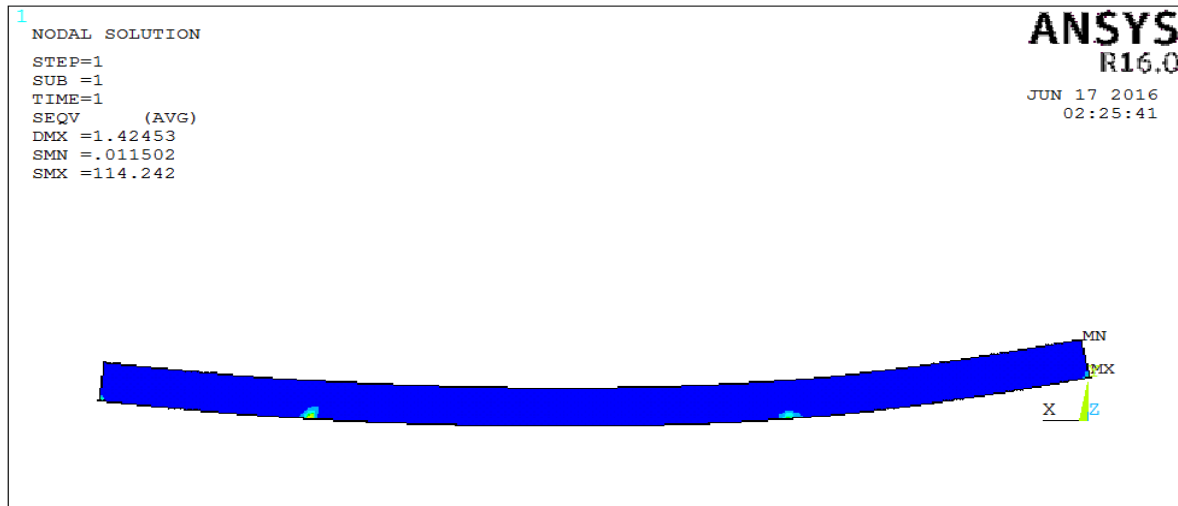


Figure 5: Von misses stress of the side frame

Table 1: Specification of the unmanned vehicle

DIMENSION	IN MM
Length of the vehicle	500
Width of the vehicle	430
Height of the vehicle	250
Distance between the two front and back wheels	400
Total weight of the vehicle	5 kilograms

6. Working:

The working operation involves controlling the unmanned vehicle by the microprocessor by giving control signals to it from remote guidance. The forward and reverse motions of the vehicle is accomplished by the forward and reverse operations of the motor. When the motor is made to run forward, if the vehicle got into obstacle if it needs to turn left or right motors on single side is made to rotate. The vehicle operation for turning is controlled by motors by seperately operating the motor as given in the figure below.

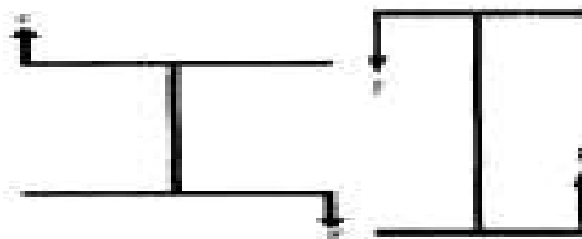


Figure 6: Motor control for left and right directional movement

The vehicle is fitted with the surveillance camera which is also operated based on the control signals from the microprocessor. The side wing attached for the lifting of the vehicle is operated by the rack and pinion system. The side wing is attached to the rack rod where the piston extension makes the side wing to pullout from the body of the unmanned vehicle. The side wing is again retracted if the pinion motor is operated in reverse direction.

7. Conclusion and Scope:

The unmanned vehicle is designed and fabricated by the aluminium and Bakelite materials. The unmanned vehicle can be operated by the remote guidance in which the zigbee electronic module has been used for controlling the forward and reverse operations of the vehicle. The lifting arm mechanism can be also actuated by the electric

motor connected to the pinion gear. The modelling of the unmanned vehicle is done using the CATIA v5 software. The side frames supporting the thrust motors are analyzed for bending stress by the ANSYS software. The future work which can be carried out is developing the control mechanisms while the vehicle is flying which may be done by remote sensing method or any other networks where the control signals are sent to vehicle from the remote guidance. The vehicle fabricated runs continuously for nearly seven minutes for the given battery power source and the flying is carried out. The future work is developing the unmanned vehicle as automated guided vehicles where it can be used in material handling systems.

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