Scholars Journal of Engineering and Technology

OPEN ACCESS

Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

Design and Development of an Unmanned Fire Fighting Robot

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DOI: 10.36347/sjet.2023.v11i03.009 | **Received:** 12.10.2021 | **Accepted:** 18.11.2021 | **Published:** 30.03.2023

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Abstract | **Original Research Article**

Burning of markets places and petroleum products tank cars especially PMS (Premium Motor Spirit) is alarming. These havocs are not only because the fire fighters do not arrive early at such scenes but the fire had grown into inferno that denies accessibility. The design, development and implementation of an unmanned firefighting robot are done to achieve a tool that will eliminate risk for fire fighters and extinguish fire perfectly to save lives and property. Development of automation systems, mobile, fire resistant, and unmanned robot to fight fire is aimed at assisting fire fighters in fighting inaccessible inferno like burning fuel tank cars, malls, petroleum products filling stations and houses. The robot will extinguish fire by water surf solution with the aid of control for its movement and up and down of the water nozzle .It is equipped with accessories that enable it for the controller to be able to manipulate and see the robot condition- MZ80 flame sensor ,and cameras controlled with an aduino microcontroller and two geared DC motors to aid movement and maneuvering .The design and development of the mechanıcal system, the electronic system, and the preparation of the necessary software are implemented with the use of CAE and FEA knowledge based software –Solidworks and Proteus for mechanical and electronic system respectively.

Index terms: Aduino Microcontroller, cameras and flame detection, Fire Fighter, Unmanned Fire Resistant Robot.

1. INTRODUCTION

Man is exposed to risk every day during his activities. Technology helps to reduce and deliver these activities fast for efficiency, time consumption and energy. Technology to design, develop and implement robot are increasing for purposes of reducing human risks, and energy, maximize time and increase profit. As alternative human and his activities,robots researchers and industriescome up with Flying, robots, wheeled robots, legged robots, humandroid robots, underwater robots etc.Firefighting Systems give prevention, extinguish, localization, or blockage of fires within enclosed spacesand installed in buildings and rooms where the fire hazard is comparatively high. The difference between systems that are operated automatically and according to a predetermined program and thosethat are actuated by an operator; and are called automatic fire protection systems, and fire protection units respectively. The fields of robotics are all of engineering that include electronics, mechanical, digital logic, artificial intelligence, nanotechnology and bioengineering. A robot can do various types of work and this is dependent on the concept of the design, duty of the robot and the environment of operation. There are simple and quite complex robots capable of doing the task assigned through the control program algorithm. Robots are designed to do tasks that people may or may not be able to do for them.

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks that the algorithm program specified and described. There are

I. Manipulator
II. Legged robot
III. Wheeled robot
IV. Autonomous Underwater Vehicle
V. Unmanned Aerial Vehicle

Robots are made to execute jobs that are dangerous or risky for humans like decontaminating Robot Cleaning the main circulating pump housing in the nuclear power plantand Menial jobs that human don't want to do likethescrubmate Robot,Repetitive jobs that are boring, stressful, or laborintensive for humans like Welding Robot. Typical knowledgebase

for the design and operation of robotics systems should be followed

i. Dynamic system modeling and analysis
ii. Feedback control
iii. Sensors and signal conditioning
iv. Actuators (muscles) and power electronics
v. Hardware/computer interfacing
vi. Computer programming

Dedicated robots are designed for a particular work. Examples of Dedicated robot are Factory robots, Tele robots, Automated fruit harvesting machines, Domestic robots, Military robots, Rescue robots, playing robots, Mining robots, Virtual tutors, Healthcare, Teacher assistants, Research robots and so on .An automatic fire-fighting system includes the use of sensor capable of detecting combustion, alarm signaling devices, fire-extinguishing equipment, starting and stopping devices, and feeders for the fire-extinguishing substance. Atomizers, foam generators, and pipe nozzles form and direct the stream of the fire-extinguishing substance, which may be a liquid, foam, powder, or gas. Fire-extinguishing substances are fed into the system from a centralized supply, such as a water supply, or from self-contained or combined feeders. The most widely used systems employ water (sprinkler and drencher systems), carbon dioxide, aerosols, or powders. A sprinkler system consists of a grid of pipelines located on the ceiling of the room, with sprinkler heads attached to the pipes by threaded connections. The opening of a sprinkler is kept closed by a disk held in a closed position by a thermal lock. If the room temperature rises to a specified point, the lock is destroyed and the disk opens, admitting water to the room

Everyday humans are confronted with many problems of inaccessibility- fire, war enemy zones, deep sea and ocean bed monitoring and very high pedestrals and mountains. Fires are among the most important of these problems. Robot industry has a lot of work in this area. There are fixed mobile robots with different featuresequipped with different sensors and transducers that detect before the fire is out, there are mobile rescue robots used for fire search equipped with rescue equipment, and cameras, fire extinguishing robots in many different models designed to assist firefighters in the fire. Sır and Umar (2007) designed a forklift robot that can be controlled by computer via RF in their work. The robot is controlled by an operator outside the workshop by computer and remote control. Xu *et al.*, (2006) designed a fire fighting robot consisting of 4 main modules with each module assembled with appropriate components to design a mobile robot capable of detecting fire at 360 degrees with 6 sensors. Darwish (2010), the difference developed by Lot Zadeh is based on fuzzy logic algorithms which vary according to the situation. The extinguishing system was implemented with a fan connected to a motor coupled to the micro-controller using an engine controller. The microcontroller software of the project was created with a logic that can be learned by using fuzzy logic. Eroğlu's (2006) studied some fundamental behaviors which have been developed to be done by the robot such as wall finding, wall mounting, avoidance of front and side obstacles, concave and convex corner turns, control of tampons, control of wheel jam. Qui, Qian and Xiang (2006) designed a dynamic robot that will overcome obstacles using ultrasonic sensors in their work. They used fuzzy logic for direction finding. With the help of robot infrared sensors produced in work, the barriers can cross different barriers without a fixed route. Parlaktuna and Eroğlu (2007) study, a map of the circulating circles of the robot was created by using Bayes update occupancy grids by using the ultrasonic sensors on the robot and the data obtained from the encoder.

2. DESIGN METHODOLOGY

A mobile firefighting unmanned robot application in this work is designed to fight fire and fire that cannot be accessed. Flow chart is developed to x-ray the order of communication and information processing to enable the maneuvering of the robot to extinguish the fire, program execution for the unmanned fire resistant robot is made possible with the aid of an Aduino microcontroller to automatically process data from scanned by sensors and captured by cameras and adequately send information to the monitor or user.

3. MATERIAL SELECTION

The choice of material in this regard is govern by the environment where the robot will be subjected; hence inflammable materials could not be used. Fire resistant materials are selected. Mild steel are used for the construction. Weight is considered in this regard to withstand the shocks and vibration from liquid solution for extinguishing flames.

4. MECHANICAL AND ELECTRONIC PARAMETERS DESIGN

The unmanned fire resistant robot is built 99% of metals mainly mild steel and the electronic system secured with glass fiber insulators so that to avoid high temperature that will lead to biasness of the electronic components, suction fans are also employed for this cooling purpose. The chaises bears the pay loads with the support of fourwheels in which the front wheels are powered by individual reducer motor. These are two wheels that make the movement of the robot and work independently from each other Rear wheels are fitted with ball bearings that do not interfere with rotation so that the wheels cannot keep the system standing and shocks with dampers are applicable for stability and cushioning of the likely vibration during movement. Fig 1 Show at a glance the circuitries that make up of the robot system, this comprises the circuit for the control of the reducer DC motors for movement, up and down

movement of the nozzle has a control circuit, the cameras have circuit, the flame detection circuit, the Bluetooth circuit and the charging and discharging circuit controlled by a central Aduino micro controller. There are four obstacle sensors, cameras, and flame detection sensors respectively mounted strategically to enable the robot know more of the surroundings.

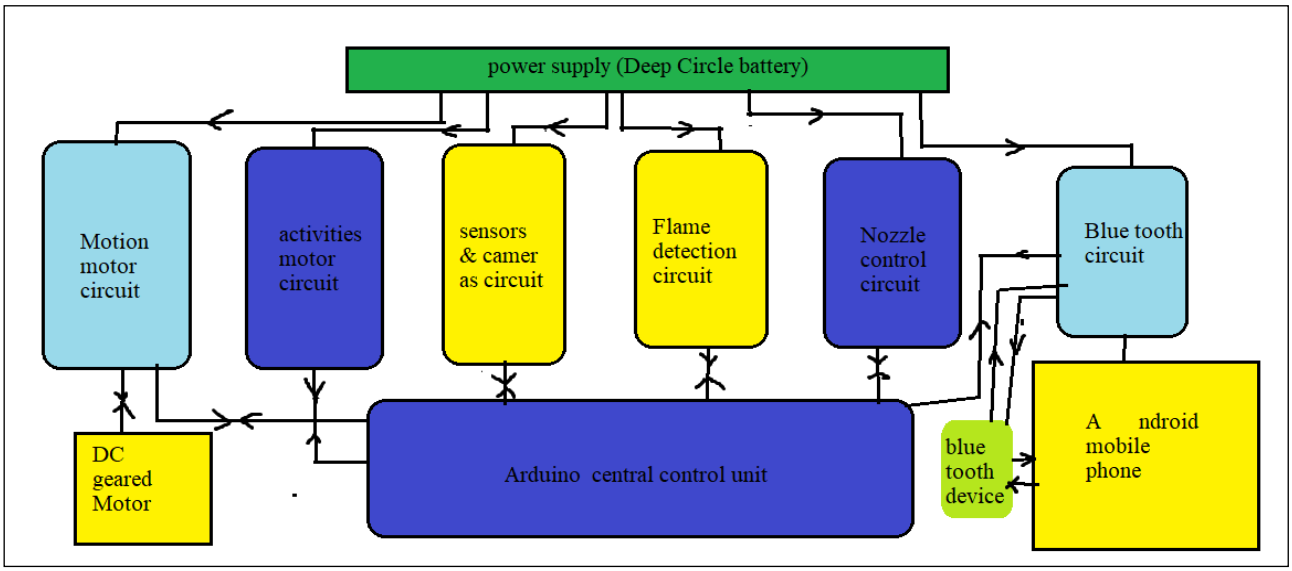


Fig 1: Diagram of the designed robot at a glance

5. FABRICATION AND IMPLEMENTATION

The design and implementation of unmanned fire resistant firefightingrobot is design with solid works using standard local materials with 25 X 56mm rectangular pipe for chaises that bears the payloads. The floor of the robot is jacketed with insulation fiber .The electrical electronic components are secured in the panel board. The body is jacketed with glass fibre for heat resistant to secure the battery and the electronics components and the microcontroller.

The items that will be used:

I. 2mm thick 25X56mm rectangular mild steel pipe
II. Fibre glass
III. 20 X 450 X 350 thick Plate
IV. Flexible heat resistant wire
V. 4 cameras
VI. 4 sensors
VII. 2 LED lamps
VIII. Dia 30mm X 1000mm mild steel shaft
IX. 2 DC Motors
X. 1 stepper motor
XI. Deep circle battery
XII. Aduino kit
XIII. Electronic component
XIV. Control app
XV. Android phone

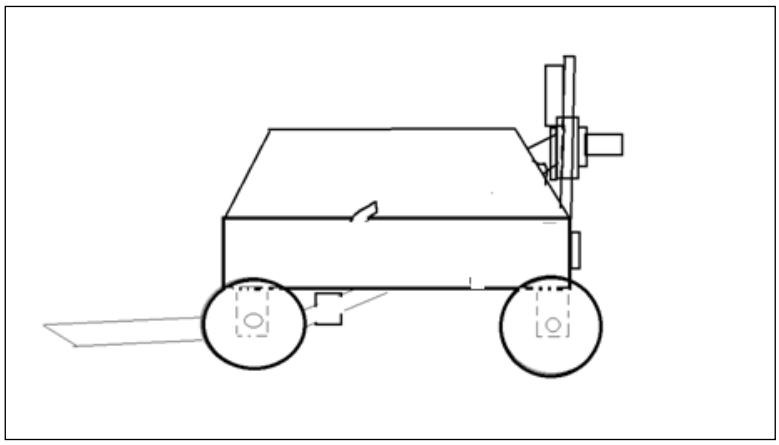
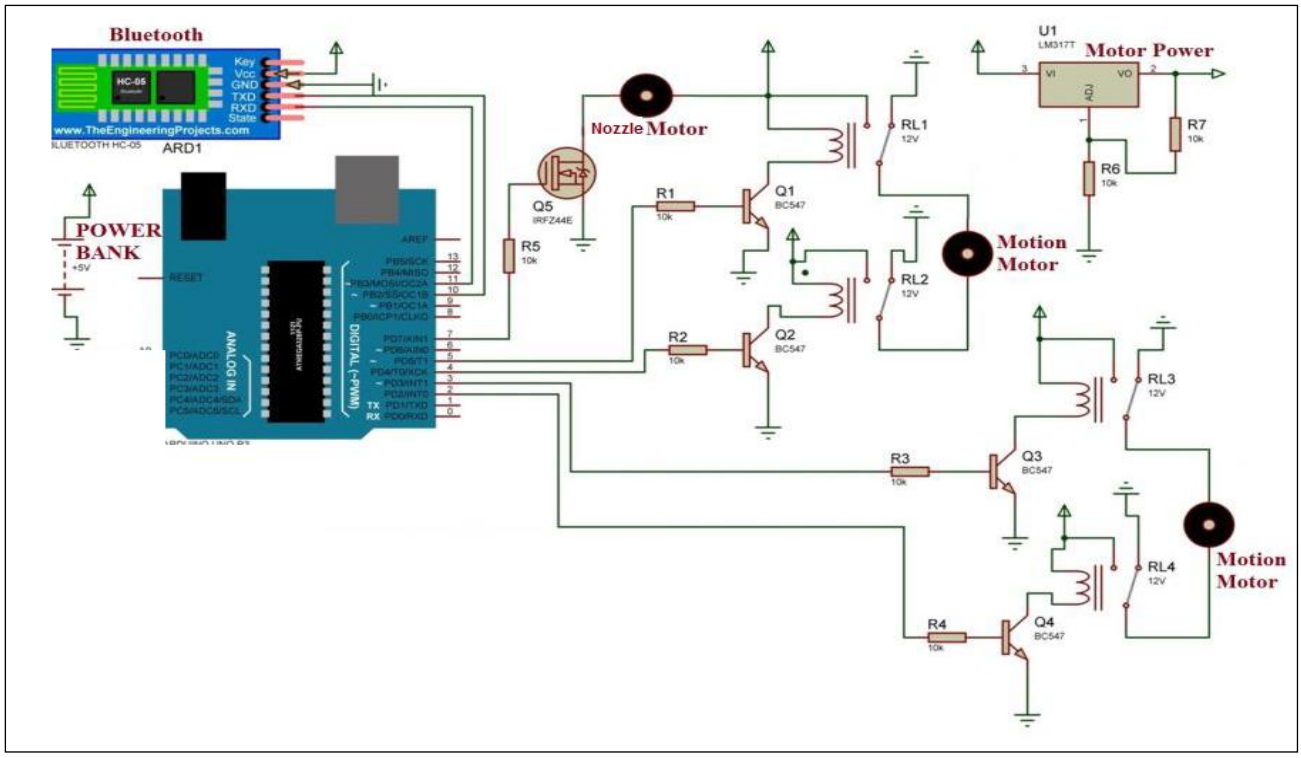
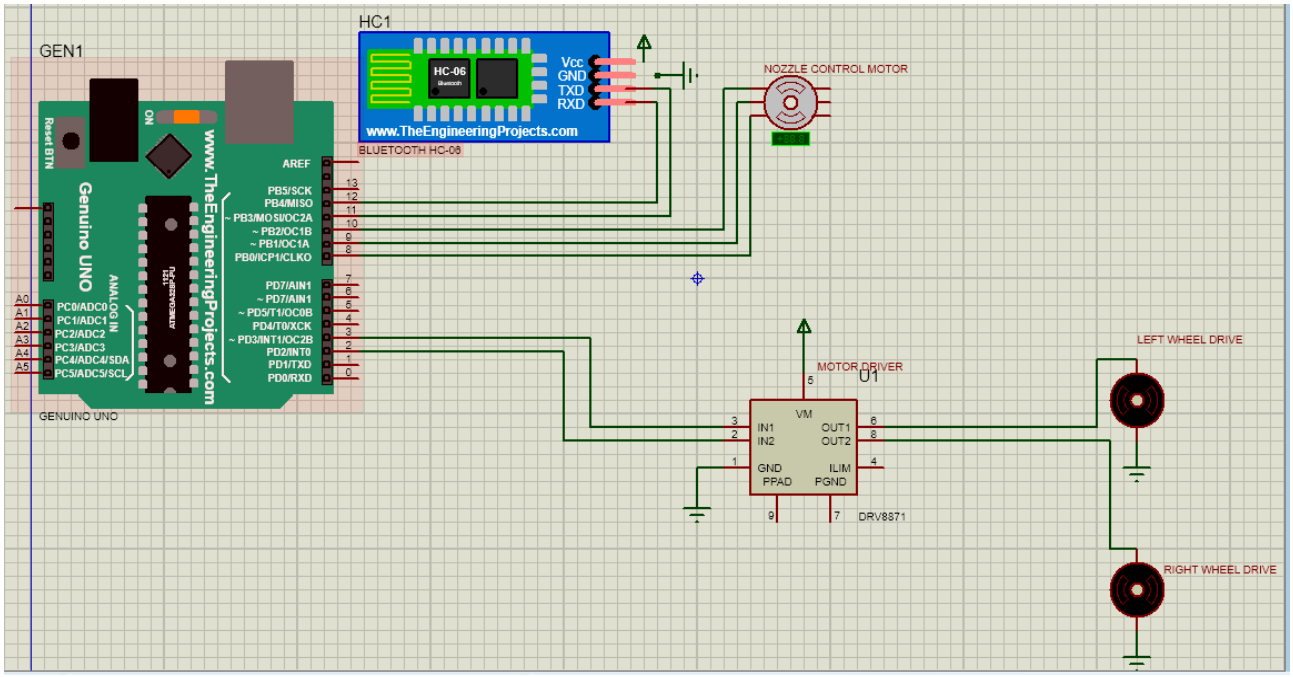


Fig 2: Schematic diagram of the model of the robot



i. Complete circuit with proteous



ii. Simple circuit

Fig 3: Circuit used in robot control

6. POWER CONSUMPTION

The power consumption becomes very important because the used of the robot is energy base, failure of the system may result the destruction of the robot even though the materials are fire and heat resistant**.** The power consumption is determined for battering size selection and the determination of charging and discharging rate .The design plan was conceptualized that the active period for the robot will be 2.hrs30mins

Table 1: Robot power requirement

s/n	Component description	Voltage rating (V)	Current rating(A)	Number of unit	Power consumption(watt)	Net power(watt)
1	DC geared motor	24	1	2	24	48
2	Stepper motor	12	0.5	1	6	6
4	cameras	12	0.15	4	1.8	7.2
5	Arduino microcontroller	5	0.035	4	0.175	0.7
6	Energy lamp	6	0.5	2	3	6
7	Bluetooth module	3.3	0.8	1	2.64	2.64
8	SUB CONTROLL COMTROLLERS	6	0.015	5	0.09	0.45
9	Weight of system					94.72
10	Miscellaneous					6
11	Total energy consumption					171.71watt

Energy dissipation on movement

Assumption

Assuming the robot had to move a distance of 20m from the mobile tank station to fire point

The energy requirement

$Work\ done = f \times d$ [1]

$f = mg$ [2]

$Work\ done = 70 \times 9.81 \times 20$

$Work\ done = 13734j$

Hence for the to and fro movement of the robot, the energy consumed is 27468j

If it take 2minuts 25 seconds to reach the fire point the power requirement is

$power = \frac{workdone}{time}$ [3]

Total time taken =290seconds

$power = \frac{27468}{290} = 94.72watt$

Therefore, the power requirement to move the robot system to and fro of a distant of 20m is 94.72watt

NB

This is done on the assumption that the palace is a plane surface hence equal energy is dissipated.

The energy is measure on the basis of the maximum time of deployment of the robot ,hence the time chosen is $2\,{}^{1}/_{2}$hrs

$Time\ of\ operation\ = 2\,{}^{1}/_{2}\,hrs$

Total Watt-Hours required = $energy * time$

Total Watt − Hours required $= 171.71 \times 2\,{}^{1}/_{2}$

Total Watt − Hours required $= 429.275watts - hour$

Assuming depth of discharging of battery is 80%

$Battery\ Amp\ Hour\ require = \frac{total\ watt\ hour\ rating}{depth\ of\ discharging\ battery\ voltage}$ [4]

$Battery\ Amp\ Hour\ require = \frac{429.275}{80} = 5.4AH$

If the battery volt is 24volt

$Battery\ Amp\ Hour\ required = \frac{total\ watt\ hour\ rating}{discharging\ rate * battery\ voltage}$

$number\ of\ battery\ require = \frac{total\ amperes\ hour\ rating}{battery\ rating\ under\ use}$ [5]

Number of battery required

No of 5 .4 Ah battery required

$No\ of\ 5.4Ah\ battery\ required = \frac{total\ ampere\ hour\ rating}{battery\ rating\ under\ used}$

The number of 5.4WH batteries =3.6 approximately 4

7. STABILITY OF THE ROBOT

The stability of the robot will be discussed stability under motion and stability at duty during fire extinguishing works. The stability under motion is governed by the total height or the CG level of the robot as well as the four wheels. A four wheeled vehicle is statically and dynamically stable except at certain speeds, heights, and curves. It is therefore statically stable owning to its four wheels and the height. The robot is design for a duty. This requires total stability. The pressure of transporting and extinguishing the fire via the nozzle is high, to avoid adverse disability as a result of the transmission pressure of the extinguishing fluid which may cause over turn of the robot acrobatically. This is overcome by weight balance and Cg very close to the ground which are used to maintain stability during the pressurized discharge of the extinguishing fluid.

8. MODEL

The model of the robot is shown with isometric and different side views.

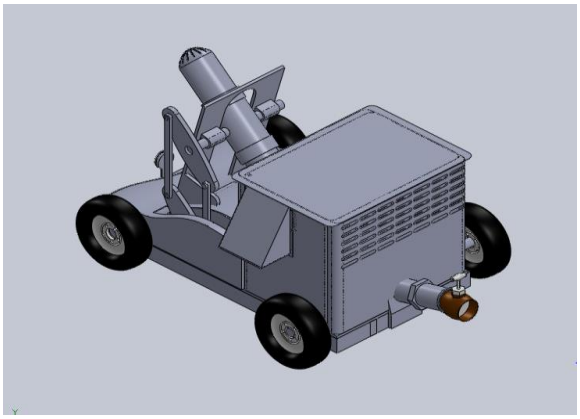


Fig 4: Back –side view of 3-D model of fire fighter

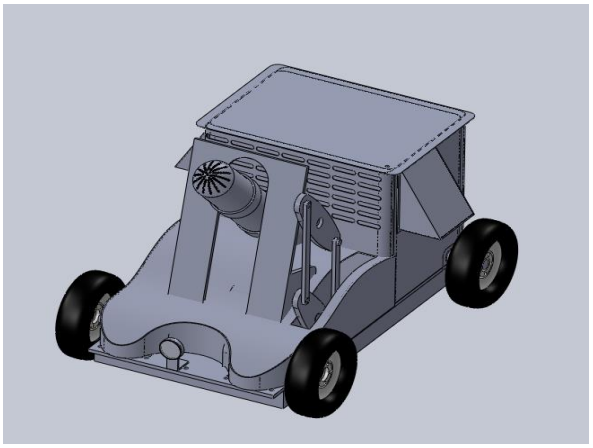


Fig 5: Front -side view 3-D model of fire fighter

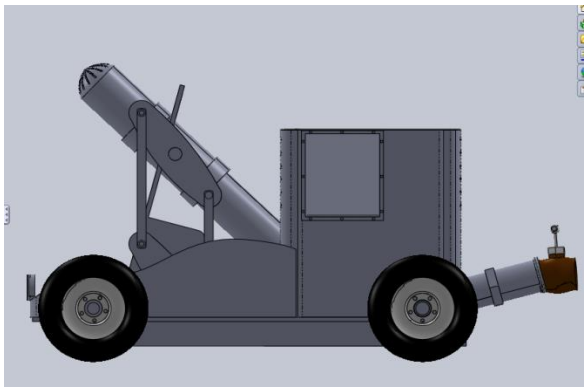


Fig side view of the fire fighting robot

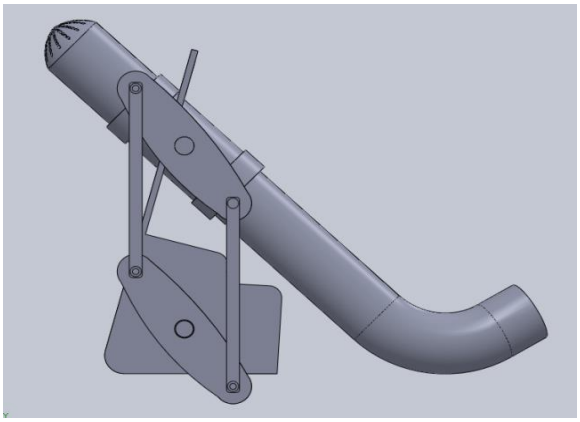


Fig 3-D side view of model of Nozzle control mechanism

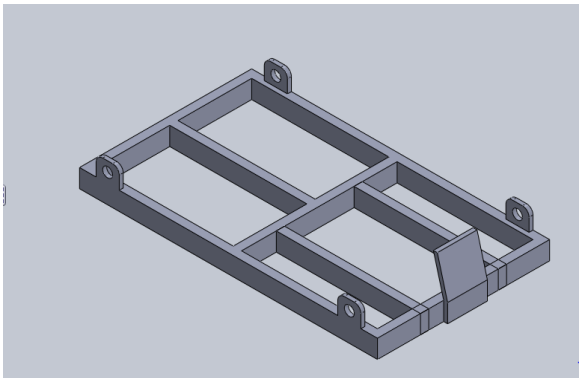


Fig 3-D model of the Chassis of the fire fighter

9. DISCUSSION

Firefightingrobot design and development is provoked with the recent occurrence of fire outbreak involving PMS tank car in Onitsha, Anambra State and burning of major markets across the country. The infernos had overtaken the activities of the fire fighters because they prove inaccessible because of high risk that would involve their lives. The material selection is done with focus on the working environment of the robot. Hence, fire resistant materials if a polymer is used and mild steel are selected, glass fiber is use used as heat resistant material to protect the electronic components. Microcontroller plays a central controller to harmonize motor controller with reductive (servo) motor, and cameras, controller and nozzle controller for nozzle direction, are coordinated and communicated through the Bluetooth controller via Bluetooth communication to the mobile phone via with a designated app.

10. CONCLUSION

Fire outbreak is prevalent in market clusters in Nigeria, malls are not left out but the risk of fire fighters employees is grievous because of unforeseen explosion and inflammable substances there in. fire incidence happening in a place is liking to charting an uncharted course because it posses danger to the fire fighter since he does not know what constitute the place or the history of the incidence. If such a place has things that can explode, the danger become too high but when such history is known, the individual will be careful. For this reason, safe guarding the lives of fire fighters, and rescuing lives and properties of an inferno on conflagration, that does not allow the fire fighters to get access, this robot is necessary to be deployed to fight the fire. Burning of PMS tank cars, filling stations, gas stations, and other areas that the fire can grow to inferno, the use of this robot is welcome. Hence, the development of this robot is of great necessary to help in fighting infernos by the Nigerian fire fighters. The robot is developed to be rechargeable, the control is initiated with the use of application adaptable on android phones, power wheels are front wheels with each wheel powered individually and the nozzle movement control by another programmable motor. Its

stability is compensated with the center of gravity (CG) and weight during operation.

11. RECOMMENDATION

It is recommended that the fabrication of this robot should be initiated using local content initiative with all the materials sourced locally and local technology deployed for excellent indigenous work there by growing and improving on the technology and growth on the country's GDP.

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