

DESIGN AND FABRICATION OF FIRE FIGHTING ROVER

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Abstract - Fire Fighting Rover can be used in operation of dangerous fire disasters in places wherein it is risky for fire brigade worker to take the operation under control. With the use of Rocker Bogie Mechanism this rover will be able to climb stairs of the building and also move smoothly on uneven road surfaces or terrains. It has been provided with the mounted Wireless Wi-Fi Camera whose live footage can be seen on an Android phone. Also the Water hose has been developed based on the principal of Universal joint, thereby making us able to direct the water jet in the desired location controlled by two 12VDC Motors. The DC geared motors are also provided at the six wheels of rover which can also be controlled using Android application. All this motors can be controlled using a microcontroller based on GSM MODULE, so there is no chance of Radio wave frequency disturbance even in high temperature and humid condition.

Key Words: Rocker Bogie, GSM Model, Water pump, water hose, Universal Joint, Chassis, DC Geared Motor, Nozzle.

1. INTRODUCTION

Fire fighters nowadays come across with dangerous situations when they extinguish fires and it is an unavoidable part of being a fire fighter. With the development in the field of robotics, human intrusion has become less and robots are being widely used for safety purpose. In our day-to-day life, fire accidents have become common and sometimes may lead to hazards that make it hard for the firemen to protect human life. Because there can be extreme loss of life and property due to lack of technical equipment which can be used to fight the fire disaster.

According to one of the report of Dec 2017 there has been total of 36,159 calamities which were recorded as a fire disaster due to different causes and failures such as electrical, mechanical, thermal, etc.

So fire brigade workers cannot reach the place of calamity instantly, so in such crucial times such Firefighting rovers can be used which are easy to be handled and their by will be able to save lives much easily without putting the lives of fire brigade workers at risk. A firefighting robot can be used to guard human lives, wealth, and surroundings from the fire accidents.

The operation of this rover can be made very easy and handy just by the use of an simple android application and with the

help of the live footage of mounted WI-FI camera the operator will not have to risk his own life and can avoid to get into dangerous scenario.

Being made with the principal of rocker bogie which was even used in the MARS mission, there is no fear of the imbalance of the rover due to any type of obstacle because the rocker arm attached to the frame are capable of overcoming any kind of obstacle and thus the need of actual suspension in the links can be avoided.

Rocker Bogie mechanism: The Rocker bogie system is the suspension arrangement used in Mars rovers introduced for Mars Pathfinder and also used on Mars Exploration Rover(MER) and Mars Science Laboratory(MSL) missions. This bogie can resist mechanical failures caused by the harsh environment on MARS. The primary mechanical feature of the Rocker Bogie design is it's drive train simplicity, which is accomplished by two rocker arms.

This rover can be used as a unit of Fire Brigade itself in case of dangerous scenarios

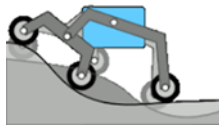
And also the main advantage of having this rover is that, fire brigade units having less taskforce can also overcome the fire easily because the men required to hold the Water hose will be eliminated and the operator of the rover being unaided and unassisted can overcome the considerable amount of fire.

Objectives of developing a Fire Fighting Rover are:

- Life safety of firemen
- Cost cutting obtainable once the efficient model is developed
- Efficient control of fire possible
- Hazardous and large scale fire disasters can be controlled in an accurate manner
- Decrease in panic parameters
- Can be used in places of High rise Infrastructure

Where there is a lack of stair heights...

Basic Working Principle of Rocker Bogie Mechanism:



- In order to go over an obstacle, the front wheels are forced against the obstacle by the rear wheels, the rotation of the front wheel then lifts the front of the vehicle up and over the obstacle

- The middle wheel is then pressed against the obstacle by the rear wheel and pulled against the obstacle by the front, until it is lifted up and over.

- Finally, the rear wheel is pulled over the obstacle by the front two wheels. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted.

- These rovers move slowly and climb over the obstacles by having wheels lift each piece of the suspension over the obstacle one portion at a time.

DESIGN CALCULATION:-

Rocker Bogie

We are calculating the following with the aim of developing the rover with overall length of 3 feet (914.4 mm), breadth of 2.5 feet (762 mm).

Height of rover from bottom of the wheel to base of chassis is 300mm.

Hence with this dimensions

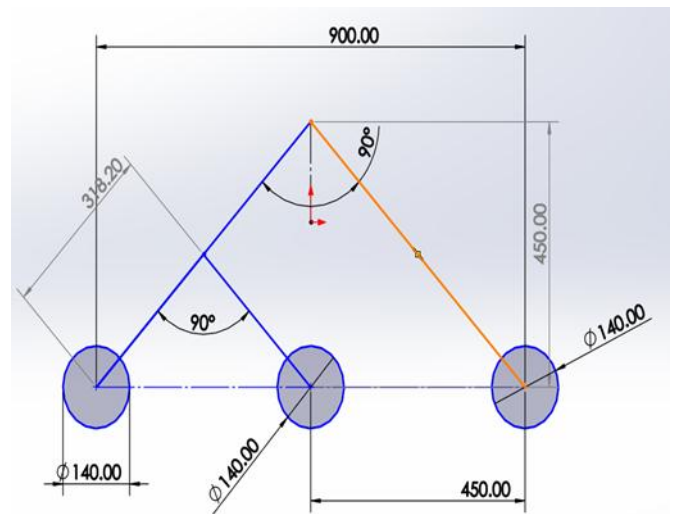
Our rover will be able to easily climb any obstacle which could be

100.5cm long and 30 cm high

Tilt Angle (θ)= $\tan^{-1}(y/x)=\tan^{-1}(30/100.5)=17$ degrees

Thereby calculating the bogie linkages:

Wheel base =Total length-(Radius of front & rear wheels)=1040-140=900mm



To achieve the stability it is required that only one pair of wheel should be in a rising position at a time.

So, the first pairs of wheels are placed at a rising position being completely horizontal and second pair of wheels are just about to rise.

Some distance between vertical edge of stair and second pair of wheels is mandatory.

Using Pythagoras theorem, in $\triangle ADE$

$$AE^2 = AD^2 + DE^2$$

$$900^2 = x^2 + x^2$$

$$900^2 = 2x^2$$

$$x = 636.6 \text{ mm (Add data from testing)}$$

$$=637 \text{ mm(Appx.)}$$

Hence $AD=DE=637$ mm

Similarly, to find dimensions for rocker linkages first two wheel pairs should be placed at horizontal position. Third wheel pair should nearly complete its rising before starting of rising of first pair of wheel.

Similarly, in this condition For length of link AC,

For $\triangle ABC$,

$$AB^2 = AC^2 + BC^2$$

$$450^2 = 2Y^2$$

$$\text{Hence, } Y=318\text{mm(Appx)}$$

$$AC=BC=318\text{mm}$$

DESIGN CALCULATION:-

DC Motor Selection

Assumptions are as follows:

Total Weight: 28 kgs(1Kg Buffer weight)

Required Velocity :1.5 m/s

Required Acceleration:0.75m/s²

No. of Drive Motors:6(for wheels)

Radius of Rover wheel: 60mm (0.06m)

Without Inclination:

Now there are two main relations to understand:

$$v=2\pi*r*RPS-(1)$$

$$T=(F*r)/N-(2)$$

In (2) T is the Torque and we can replace F with m*a

where m is the Mass of the robot in Kg.

Now using above data in (1) to solve for RPS (Rotations per second), we get

$$RPS = \frac{2m/s}{2\pi*0.06m}$$

Convert RPS to RPM (Rotation per minute) by Multiplying RPS by 60, we get,

RPM = 318 — required at any instant at for the robot to run at the desired velocity.

Now we need to find the Torque of the motor required. To find this we will use (2). We get,

$$T = \frac{28*0.75*0.06}{6}$$

We also have to compensate for the motor's gear and wheel slip. To do that, we do,

$$T*100$$

Efficiency

Assuming efficiency to be 60% is fair. So after calculating, we get,

T = .35 Nm — required at any instant for our robot to accelerate at the desired rate.

Small DC Geared motors are not rated in Nm as it is a very big unit. To convert it to more reasonable unit of kgf-cm, we do,

$$(T*100)/9.8 \text{ — Torque in kgf-cm}$$

$$T = 3.57 \text{ Kgf-cm}$$

The calculated RPM and Torque are the continuous output we need from the motor but DC motors are not specified in this manner. They are specified by their No-load Speeds and their Stall Torque.

It's a rule of thumb that the stall torque of the motor should be 4 times your calculated torque. And no-load speed of the motor should be higher by 25% or more.

Thus we need a motor of:

$$\text{No load Speed} = 397.5\text{Rpm} = 400 \text{ Rpm(Appx)}$$

$$\text{Stall Torque} = 14.28 \text{ Kgf-cm}(3.57*4)$$

$$= 14.28*0.0980665$$

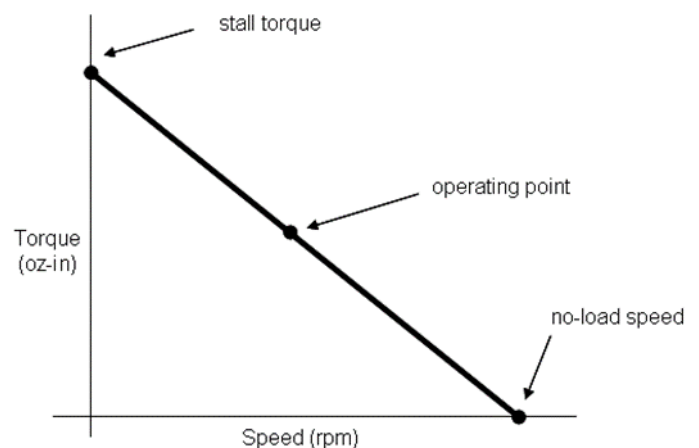
$$= 1.4 \text{ N-m}$$

Product of speed and torque of motor is constant. If one reduces the other must increase. Also,

T is proportional to current drawn by the motor

Speed of the motor is proportional to supplied voltage

In a DC geared motor, torque and speed are related by the below graph (Forget the units!)



Therefore, if our Stall Torque is 4 times more than our required torque and our motor is running at the required torque, then, our motor will be operating at 75% of its No-load Speed at that time.

Also calculate the continuous current that your motor will draw at any point in your application. For that obtain the power that your motor will be delivering at any time by using

$$\text{Power (Kw)} = (\text{Speed} * \text{Torque}) / 9.5488 = (400 * 1.4) / 9.5488 = 58.6 \text{ Kw}$$

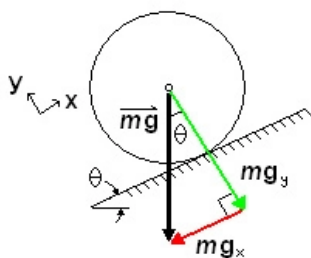
; (where speed is in RPM & Torque is in Nm)

$$\text{Current} = (\text{Torque} * \text{Speed}) / \text{Voltage}$$

From the above equation of equation of power in DC circuits, we can obtain the current draw by the motor in terms of Torque and Speed.

With Inclination:

In order for a robot to roll up an incline at a constant velocity (no acceleration or deceleration) it must produce enough torque to “counteract” the effect of gravity, which would otherwise cause it to roll down the incline. On an inclined surface (at an angle theta) however, only one component of its weight (mg_x parallel to the surface) causes the robot to move downwards. The other component, mg_y is balanced by the normal force the surface exerts on the wheels.



Ta

$$mg_x = mg * \sin(\theta)$$

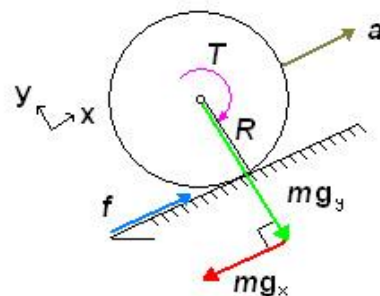
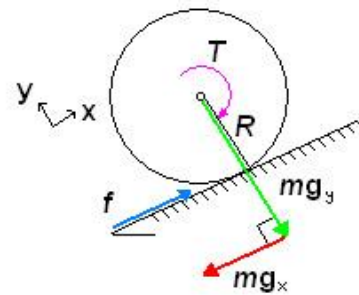
$$mg_y = mg * \cos(\theta)$$

In order for the robot not to slide down the incline, there must be friction between the wheel and the surface. The motor in a heavy truck may be able to produce 250 horsepower and significant torque, but we have all seen (in person or in video) large trucks simply spinning their wheels as they fall backwards on an icy street. It is friction (f) that “produces” the torque.

The torque (T) required is:

$$T = f * R$$

To select the proper motor, we must consider the “worst case scenario”, where the robot is not only on an incline, but accelerating up it.



Note now that all forces (F) are along the x and y axes. We balance the forces in the x-direction:

$$\sum F_x = M * a = f - (m * g_x)$$

Inserting the equation for torque above, and the equation for mg_x, we obtain:

$$M * a = T / R - M * g * \sin(\theta)$$

Rearrange the equation to isolate T:

$$T = R * M * (a + g * \sin(\theta))$$

This torque value represents the total torque required to accelerate the robot up an incline. However, this value must be divided by the total number (N) of drive wheels to obtain the torque needed for each drive motor. Note that we do not consider the total number of passive wheels as they have no effect on the torque required to move the object aside from adding weight.

$$T = \frac{R * M * (a + g * \sin(\theta))}{N}$$

The final point to consider is the efficiency (e) in the motor, gearing and wheel (slip).

$$T = \frac{R * M * (a + g * \sin(\theta)) * (100 / e)}{N}$$

In most cases you will find that using inexpensive parts decreases the efficiency of the system and even 58% total

efficiency is rather high. The lost energy is transferred mostly to heat and noise.

Taking into consideration the efficiency of the system increases the torque required to compensates for inefficiencies. Total power (P) per motor can be calculated using the following relation:

$$P = T * \omega$$

T is known from above and the angular velocity (ω) is specified by the builder. It is best to select the maximum angular velocity to be able to find the corresponding maximum power. Knowing the maximum power and the supply voltage (V) which the builder chooses, we can find an idea of the maximum current (I) requirements:

$$P = I * V$$

The two equations above are used to produce the following relation:

$$I = \frac{T * \omega}{V}$$

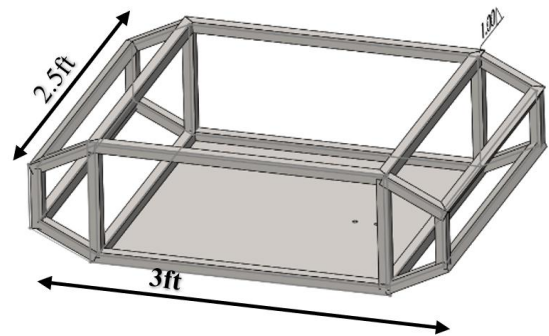
Finally, the capacity (c) of battery pack required can be estimated using the equation:

$$c = I * t$$

MATERIAL SELECTION

COMPONENT	MATERIAL
DC Motor	24 V 400 RPM, 2 N-m Torque
Frame	Mild steel 1sch. 40 rectangular pipe
Rocker Bogie Mechanism	Mild Steel
Water hose/Nozzle	Brass Standard
Pipe	Nylon plastic
Wheels	-
Water Pump	Cast iron, 120W ¾ inch, Max Pressure: 1.5 bar, Max flow rate: 50l/min

FINAL CHASIS DESIGN(3D MODEL)



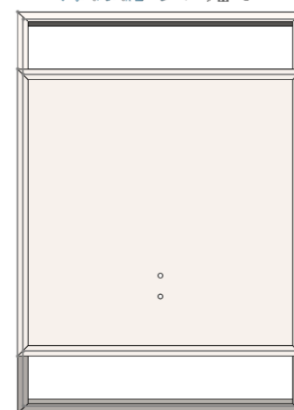
ISOMETRIC VIEW



FRONT VIEW



SIDE VIEW

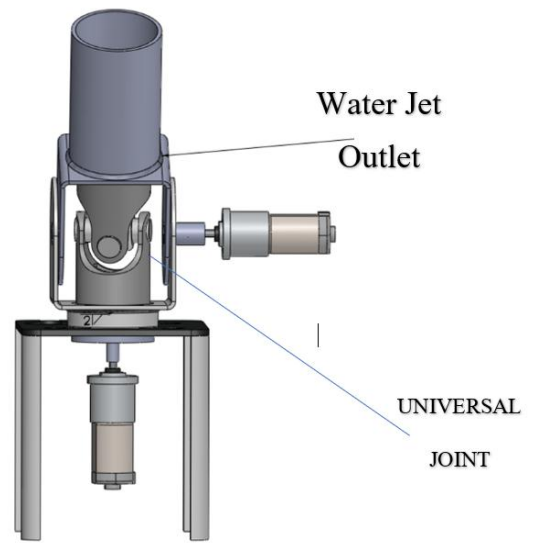
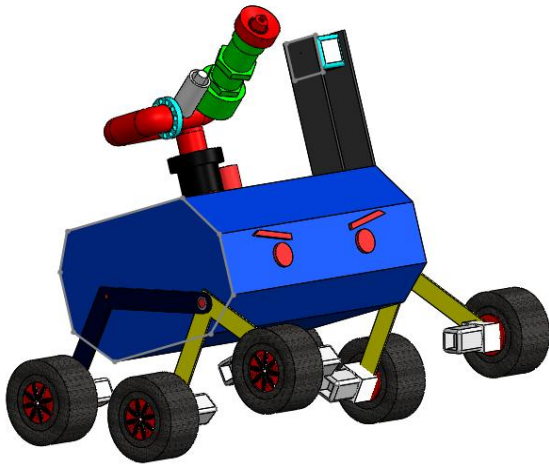


TOP VIEW

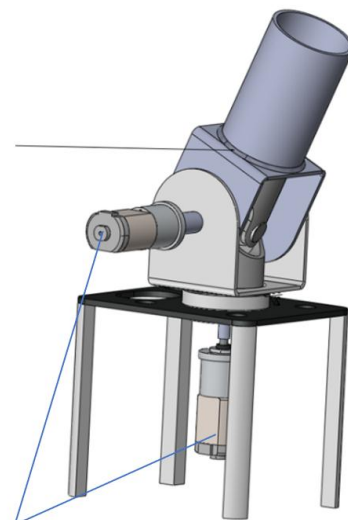
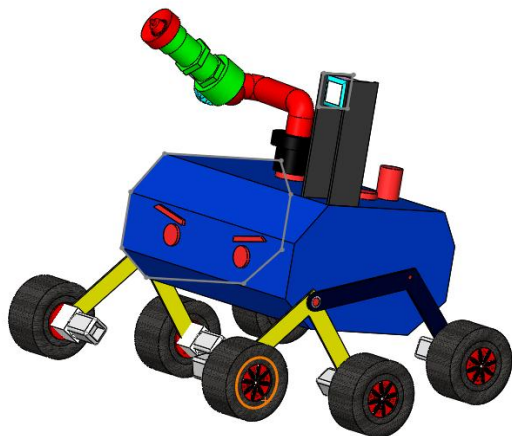
FINAL CHASIS ASSEMBLY(3D MODEL)

WATER JET ROTATION MECHANISM

ISOMETRIC VIEW 1:

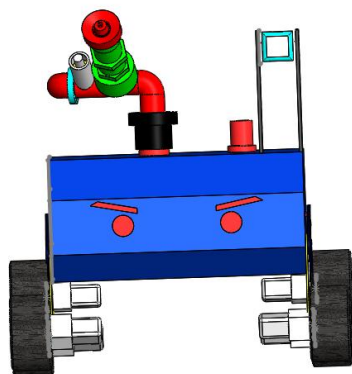


ISOMETRIC VIEW 2:



12V GEARED DC MOTORS

FRONT VIEW:



Universal joint has been used to design the water jet outlet

-Two 12v Geared dc motors will be controlling the motion of the water joint in the desired location

-The outer motor in the horizontal attachment will help us move the Jet in up and down motion

-And the motor at the bottom will help us rotate the jet in circular direction without any constraints

Hence , with the simple use of easily available universal joint which is easily available in the market we can provide at least 2 degree of freedom

-And along with the simultaneous movement of the water jet and the rover itself we can provide at least 3 degree of freedom.

Other Crucial Components of the rover are as follows:

- Wheels
- Rocker arm
- Water hose connection
- High Pressure water pump
- Outer Frame

WHEEL :

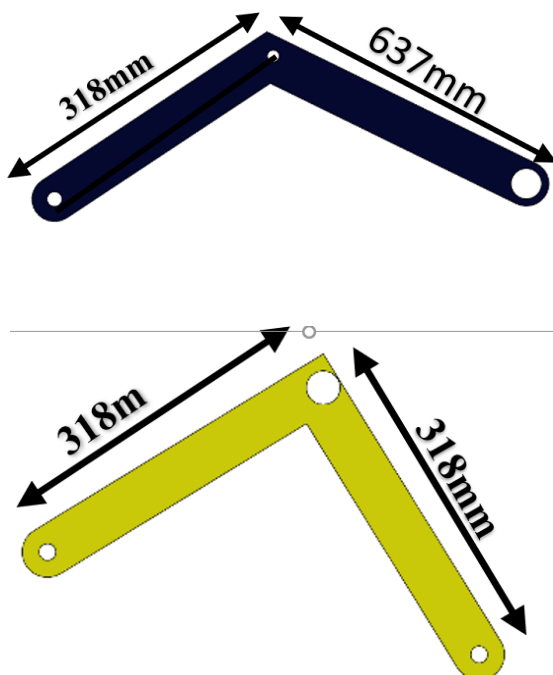
120mm Diameter

Wheel width: 35 mm



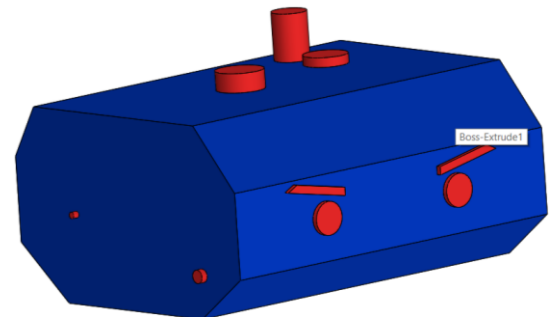
ROCKER ARMS:

Made up of 6mm MS Sheet

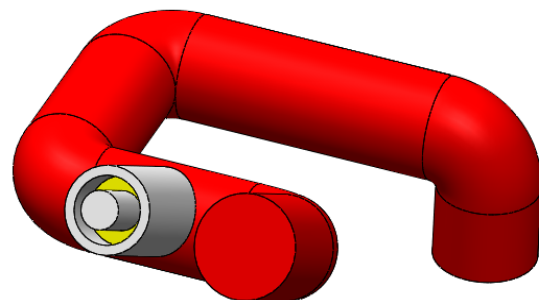


OUTER FRAME:

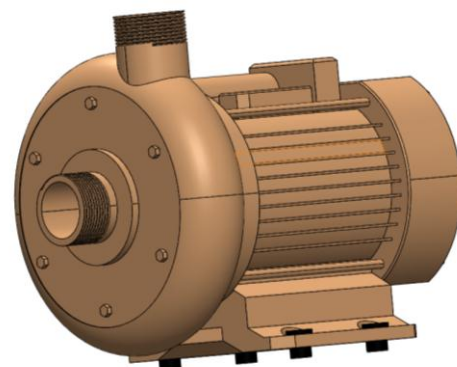
Made up of 5mm MS Sheet



WATER HOSE CONNECTION:



HIGH PRESSURE WATER PUMP:



CONCLUSIONS

This paper gives a detailed mechanism about the robot that continuously monitors, intimates the respective personnel and extinguishes the fire. In the industry if any fire accident occurs, there is a need of person to monitor continuously and rectify it.

The operator of the rover will be able to control the fire easily with the simple use of Android application interface. This way there will be less need of entering into real disaster scenario and much more risk can be eliminated.

With the usage of GSM modem there will be minor or negligible interference into the frequency due to high temperature conditions. And hence, there will be almost no danger of communication loss.

And being constructed using the rocker bogie principle, with the usage of lightweight and long water pipes the fireman or the operator will not be needed to enter the buildings or infrastructures until the point of manageable fire disaster condition, as the rover will be able to move over the stairs without any chance of imbalance in the motion.

ACKNOWLEDGEMENTS

The presented design of the Firefighting rover is compatible for use in disastrous conditions of fire.

The use and operation of the rover should not be a problem according to our research and analysis.

Such wonderful design of rover was not possible without the help and support of our Guide Prof. Marnish Modi.

Also, the enthusiasm with which Prof. Piyush Surani has backed us during initial stages was very helpful.

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