STUDY & DESIGN OF FIRE DETECTING & FIRE EXTINGUISHING ROBOT

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ABSTRACT

This paper includes a detailed study of fire fighting robot and how this robot is going to useful in fire-prone areas. It is going to monitor prescribed area with the help of drive mechanism which is operated by lithium batteries and IR sensors which are very useful in detecting fire. Electronics also plays an important role here. Motor is used to operate the fire extinguisher. The procedures of selection of drive-trains and various aspects of motor are explained in this paper. There are various issues between wheel and track drive selection. Analytical work of chassis where all parts are assembled on the chassis is also shown.

Keyword- *Fire extinguisher, drivetrain, wheel drive, track drive, Motors*

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1. INTRODUCTION

We are living in times of resurgence particularly to mention in Robotics, igniting the panorama of technological development. It can be stated that robotics are affecting all fields of life and that mankind will become even more dependent on robotics in the years to come. At the centre of this revolution, making it happen will be the practitioners of Robotics. Leveraging the technologies available and implementing automated machines in places where human interaction is hazardous and ineffective. Considering the trajectory the field is taking, there is a lot more work that needs to be done for the advancement in this field.

Fire detection and extinguishment are the hazardous job that invariably put the life of a fire fighter in danger. By putting a mobile robot to perform this task in a fire-prone area, it can aid to avoid untoward incidents or the loss of lives. Hence design an Autonomous Fire Fighting Mobile Platform that is able to monitor a prescribed area, detect for the occurrence of fire, locate for exact location of fire source, and extinguish the flame.Organizations, industries and households have problems dealing with fire fighting due to cylinders, sparks, open stoves etc. In these situations human action comes to a suspended state or in fact a halt. With the use of robotics, development of fire detecting and extinguishing robot could suffice a solution to these problems. This project work will include design of the chassis, selection of drive mechanism either track drive or wheel drive. [1]

2. DRIVE TRAIN ATTRIBUTES TO COMPARE

Agility	- Ability to move in x and y axis as well as rotate about the z axis simultaneously
Strength	- Push robots and/or game pieces resist defense from all sides of the drivetrain
Number of Motors	- Number of motors allowed on robot is limited. Most drive trains use 4 motors to power wheels, and additional motors to rotate wheel modules, to translate the robot sideways and for other robot functions.
Programming	- Ideally does not require sensor feedback (e.g. wheel module angle) or advanced algorithm to calculate individual wheel speed/power.

Ease to Drive - Intuitive to control so little practice is required to be competitive. Though some drive trains have the ability to move sideways doesn't mean the driver will use it; often drivers end up turning the robot because it is more natural and going sideways generally slows the robot.

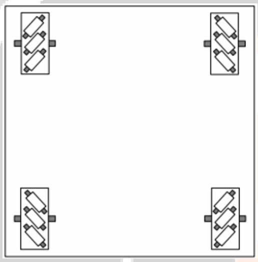
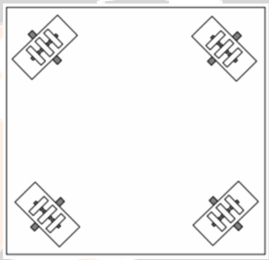
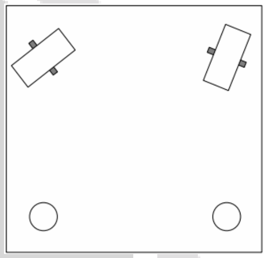
Traverse Obstacles - The ability of a drivetrain to traverse ramps, bumps or steps.

Design - Following points are considered in the design of the robot.

- Cost
- Ease to design (select components and choose dimensions)
- Ease to manufacture
- Ease to assemble
- Ease to maintain/repair
- Weight

Comparison between various drives is given in table 1 below :-

Table 1- Comparison between drives [2]

	Mecanum drive	**Holonomic drive**	**Swerve drive**
Description	 Wheels with angled rollers	 Wheels with "straight" rollers (omni-wheels)	 Independently steered drive modules
Advantages	- compact design - high load capacity - simple to control - less speed and pushing force when moving diagonally	- low weight - compact design - simple to control - less speed and pushing force when moving diagonally	- conceptually simple - simple wheels - continuous wheel contact - high load capacity - robust to floor conditions
Disadvantages	- conceptually very complex - discontinuous wheel contact - high sensitivity to floor irregularities - complex wheel design	- conceptually more complex - discontinuous wheel contact or variable drive-radius - sensitive to floor irregularities - lower traction	- complex mechanical design - heavy and massive design - complex to program and control - high friction and scrubbing while steering

3. EVALUATING ALTERNATIVE CHOICES

A decision matrix is a chart that allows a team or individual to systematically identify, analyze, and rate the strength of relationships between sets of information. The matrix is especially useful for looking at large numbers of decision factors and assessing each factor's relative importance. A decision matrix can be used for multiple purposes. It may be used when trying to identify what decisions or solutions are most viable, or to help select a problem to work on. It is frequently used during quality planning activities to select product or service features and goals and to develop process steps and weigh alternatives. For quality improvement activities, a decision matrix can be useful in selecting a project and in evaluating which solutions or decisions are the most viable. A decision matrix or selection matrix is essentially an array that presents on one axis a list of alternatives, options or solutions. These are evaluated with respect to a list of criteria which are weighted by their respective importance in the final decision. These criteria and their weights are shown on the other axis.

3.1 How to use the tool

This tool may be utilized using the COWS method as follows:

- *C* – Criteria. Develop a hierarchy of criteria, also known as decision model. Place these on one axis.
- *O* – Identify the options, also known as solutions or alternatives. Place these on the second axis.
- *W* – Assign a weight to each criterion based on its importance in the final decision.
- *S* – Rate each option on a ratio scale by assigning it a score or rating against each criterion. The score is calculated as Rating x Weight.
- The scores are then evaluated, and solutions with the highest scores are the ones that best meet the criteria.

Table -2: Decision matrix

R=Rating S=Score	Weight	Tank		Swerve		Slide		Mecanum		Holonomic	
		R	**S**	**R**	**S**	**R**	**S**	**R**	**S**	**R**	**S**
Agility	10	3	30	5	50	5	50	5	50	5	50
Strength	5	4	20	5	25	1	5	1	5	1	5
Motors	5	5	25	1	5	3	15	5	25	5	25
Program	5	3	15	1	5	2	10	2	10	1	5
Drive	10	5	50	3	30	3	30	2	20	1	10
Traverse	5	5	25	4	20	5	25	3	15	1	5
Design	10	5	50	1	10	4	40	4	40	3	30
Total	50	30	215	20	145	23	165	22	165	17	130

4. WHEEL V/S TRACK

Increase in tire diameter, increases vehicle ground surface contact area, which ultimately increases platform drawbar pull (DP). DP is the total thrust minus the soils resistances. Additional increases in wheel diameter will ultimately increase the DP to the desired levels. The track vs. wheel tradeoffs for robot vehicle mobility has many different facets. Low-pressure pneumatic tires using adaptive tire pressure can dramatically reduce ground pressure. Here different types of relatively small robotic vehicles traversing highly cohesive terrain such as wet clay. A small, four-wheel robotic platform with 12” diameter tires is shown in Fig. 1a. The rectangular foot print is 3”x4”, weight is 1000 lb. and the tires are separated by a distance of 36”. Each tire has a total contact area of 12 sq. in. and an overall surface contact area of 48 sq. in. The ground pressure of the vehicle is 21 psi. This model predicts that the wheels will sink 2.3” below the terrain surface. At this depth, the soil resistance is larger than the maximum soil thrust generated by the vehicle.

A negative value for DP indicates that the vehicle is incapable of moving forward at a nonzero speed. One possibility for improving tractive effort might is to increase the net payload or gross vehicle weight. When a 200 lb payload is added to a baseline vehicle weighing 1000 lbs, the wheels sink deeper into the soil. The motion resistance increases and DP remains a negative number. This type of soil is soft and deforms too easily to support the larger ground pressure. This technique does work, however, for more rigid terrains with smaller soil sinkage parameters.

When the diameter of the tire is increased to a 3”x6” feet print as shown in Fig. 1b, the total ground contact area of the vehicle is increased to 72” sq. in. and the soil sinkage is reduced to 1.5”. The soil resistance is reduced to a point where the vehicle is now able to move with a positive DP. In summary, increase in tire diameter increases vehicle ground surface contact area, which ultimately increases platform DP. Additional increases in wheel diameter will ultimately increase the DP to the desired levels. At this point, however, there will be several tradeoffs among various design parameters including turning radius, engine torque and gearing, suspension design and roll over that will limit practical increases in wheel and tire diameters.

An alternative approach might also be used to add additional sets of wheels. Fig. 1d displays the same robotic platform with a 6x6 wheel configuration. When 12” diameter wheels are used in the design, they produce a 3”x4” foot print. The amount of surface contact area is equivalent to the 4x4 wheel design with the larger tires. By increasing the size of the six tires to allow for a 3”x6” foot print, the platform surface area is increased to 108 sq. in. The ground pressure decreases to 9.1 psi and the soil sinkage reduces to 1”. The net vehicle tractive force increases while the DP doubles in value. The same platform with a track configuration is shown in Fig. 1c. Each track is 25” long and 3”.

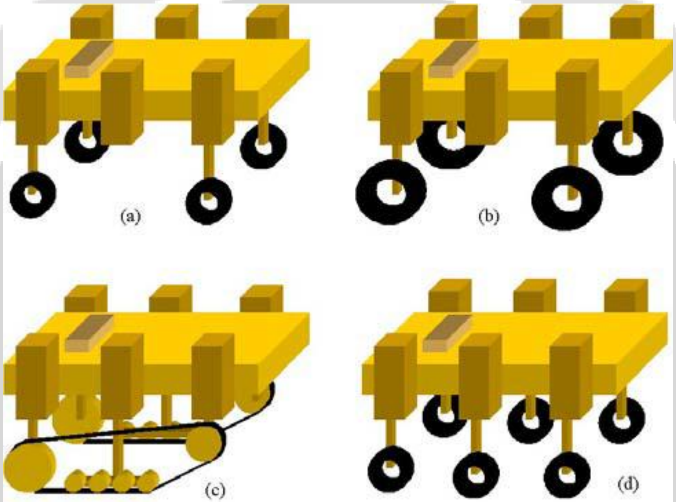


Fig. 1- Robotic vehicle

a-small wheel b-large wheel c-track d-more number of wheel [3]

The ground pressure decreases to 6 psi and soil sinkage to 0.6”. The DP increases by a factor of 14 as compared to the original 4-wheeled vehicle, 4 times greater than the platform with enlarged tires, 4 times larger than the six-wheeled vehicle with 12” diameter wheels, and 2 times larger than the six-wheeled vehicle with larger diameter wheels. When an additional 200-lb payload is placed on the tracked vehicle, the tractive effort remains unchanged while the DP decreases somewhat due to additional soil sinkage. This example shows some of the mobility tradeoffs that can be made in a plastic soil type such as wet clay. The vehicles ability to traverse in this type of terrain is dependent on the overall design of the running gear configuration and the amount of ground contact surface area. [3]

5. MOTOR SELECTION

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 ‘θ’) 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. (Fig. 2)

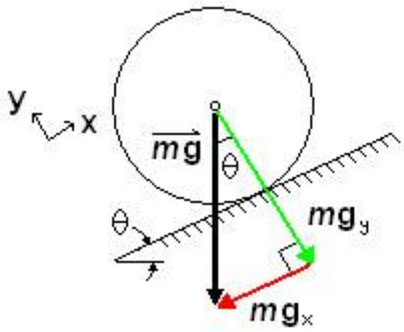


Fig. 2- Free body diagram of wheel contact

$$mg_x = mg \times \sin(\theta) = 12 \times \sin(10) = 2.084\ N$$

$$mg_y = mg \times \cos(\theta) = 12 \times \cos(10) = 11.81\ N$$

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 in large trucks generally, the wheels keep spinning as they fall backwards on an icy street. It is friction (**f**) that "produces" the torque. (Fig. 3)

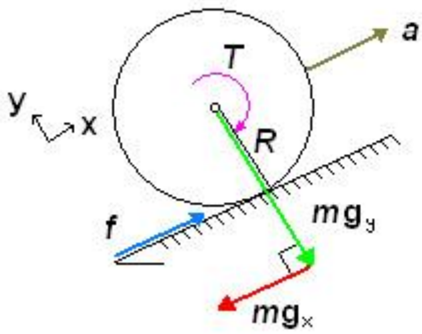


Fig. 3- Free body diagram with acceleration

The torque (**T**) required is:

$$T = f \times R$$

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.

Now that all forces (**F**) are along the x and y axes, balance the forces in the x-direction:

$$\sum F_x = M \times a = M \times g_x - f$$

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

$$M \times a = M \times g \times sin(\theta) - \frac{T}{R}$$

Rearrange the equation to isolate T:

$$T = (-a + g \times sin(\theta)) \times M \times R = 0.422Nm$$

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 the total number of passive wheels are not considered as they have no effect on the torque required to move the object aside from adding weight.

$$T = \frac{\left(\text{-a} + \text{g} \times \sin\left(\theta\right)\right) \times \text{M} \times \text{R}}{N} = 0.211Nm$$

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

$$T = \left(100 / e\right) \times \frac{\left(-\text{a} + \text{g} \times \sin\left(\theta\right)\right) \times \text{M} \times \text{R}}{N} = 0.3150Nm$$

This increases the torque required and compensates for inefficiencies.

Total power (**P**) per motor can be calculated using the following relation:

$$\text{P} = \text{T} \times \omega$$

T is known from above and the angular velocity (**w**) 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, an idea of the maximum current (**I**) requirements is obtained:

$$P = I \times V$$

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

$$I = \frac{\text{T} \times \omega}{V} = \frac{166.6}{12} = 13.88amp$$

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

$$c = I \times t = 7Ah$$

This is the battery required per motor. To obtain a total battery pack required for the robot, multiply this value by the number of drive motors.

6. IR SENSORS

IR Sensors work by using a specific light sensor to detect a selected light wavelength in the Infra-Red (IR) spectrum. Since the sensor works by looking for reflected light, it is possible to have a sensor that can return the value of the reflected light. This type of sensor can then be used to measure how "bright" the object is. Thus the IR Sensors are used on the robot to detect the intensity of the reflected light thus giving the brightness of the object where as by detecting the selected wavelength in the Infra-Red (IR) spectrum the degree of hotness of the object can be measured. If the degree of brightness and the level of hotness is more than the specified values the IR sensors give alarm to the robot and the Fire extinguishing system is activated.

7. CHASSIS

Chassis is considered as a framework to support the body, motor and other parts which make up the robot. Chassis lends support and rigidity to the robot. In this paper, modelling of fire detecting & extinguishing is shown, also analysis of chassis in ANSYS is done. Fig. 4 shows Catia model of fire extinguishing robot.

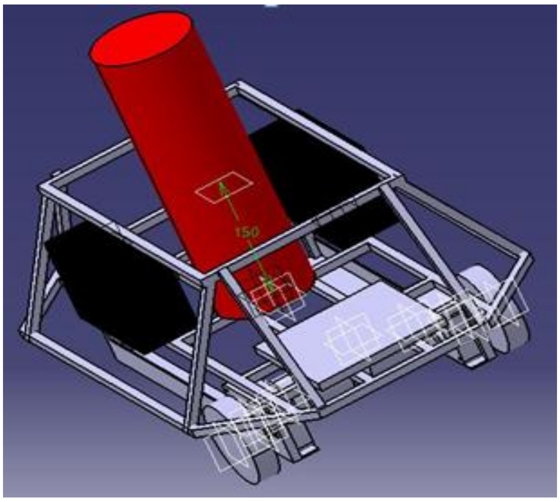


Fig. 4- Catia model of Fire fighting Robot

From Fig. 5, it can be understood that maximum deflection can be 0.0078 mm. This is acceptable deflection. Fig. 6 shows von-Mises stress, maximum stress is 2.33MPa. Fig. 7 shows working model of fire extinguishing robot.

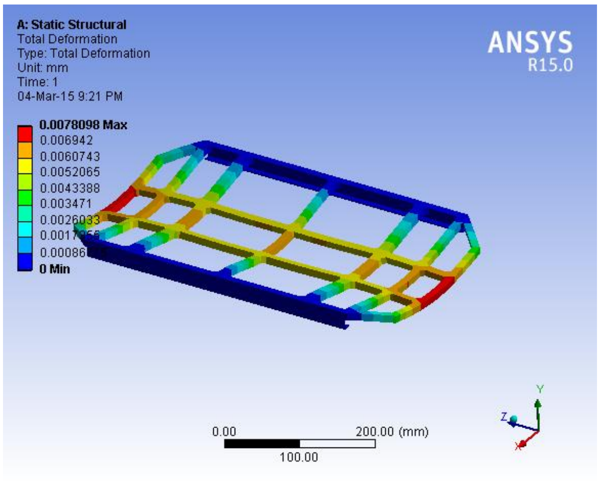


Fig. 5- Chassis analysis in ANSYS

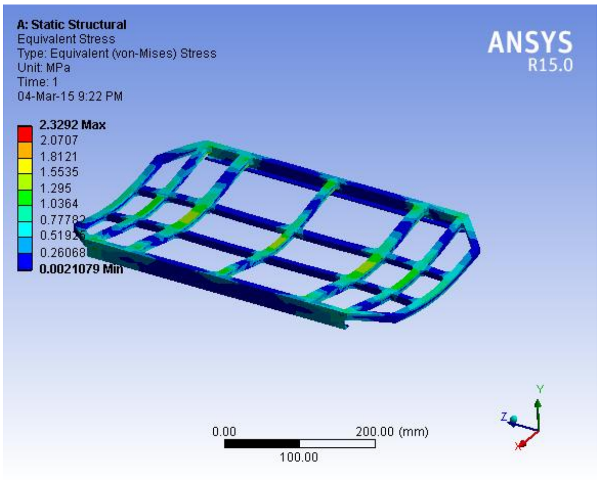


Fig. 6- Chassis analysis in von-Mises stress

Fig. 7- Working model of Fire extinguishing robot

7. CONCLUSION

From stress & deformation analysis, decision matrix and calculations, following conclusions can be drawn

- Track drive is suitable for required task which is proved from matrix method. According need drive selection done by matrix method.
- Wheel drive has some limitation but can be eliminated by increasing diameter or increasing number of wheels.
- Motor calculation must be done by considering inclined surface, so it can be used in worst condition.
- From above ANSYS results, Chassis design is safe.

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