# INDIAN INSTITUTE OF TECHNOLOGY JODHPUR

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DEPARTMENT OF MECHANICAL ENGINEERING

(B.TECH.)

## PROJECT TITLE

# Design, Simulation and Demonstration of Leg for Quadruped Robot

## Design Credit Course Report (MEN1010)


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**Submitted to:-**

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# Wheeled Quadruped Robot

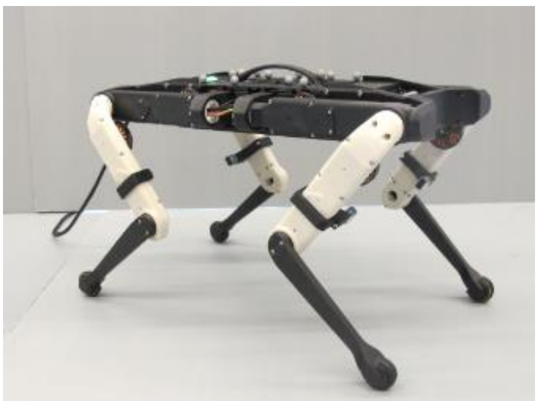
## Abstract:-

This project aims to design a quadruped robot with wheels and conduct kinetic simulation on it. There is design work involved in crucial assemblies like gears and power transmissions. The experiment focuses on how quadrupeds' legs move under various conditions.

## I. INTRODUCTION

Robots are made for a variety of uses and are made to carry out activities in a variety of environments. Wheeled quadruped robots are mechanized animals that can move on four wheels and have a quadrupedal body type. They combine stability and mobility to handle a variety of terrains with improved agility and flexibility.

This study will provide an examination of the kinematic studies and design related to the movement of a wheeled quadruped robot. The wheels on the current model of quadruped robots are attached at the joints and feet, making them suitable for a variety of terrains.



Reference: Open Dynamic Robot Initiative

# II. METHODOLOGY

## Design Overview:-

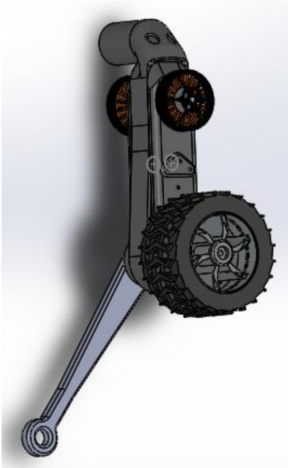


**Fig. (a) Leg of Quadruped Robot**

**Created by Bhupendra (B21ME019)**

In fig. (a) We have two motors are present in this quadruped robot leg, which are necessary for both lower limb and wheel motion at the joint. The timing belt and gear system that make up the upper limb are referred to as the actuator module constituting a pivotal component instrumental in coordinating precise movement of robot.

### Wheel design Data:-

| Name | Standard Rover Wheel |
|---|---|
| **Wheel diameter** | 90 mm |
| **Tyre weight** | 110 g |
| **Tyre width** | 45 mm |
| **Material of Construction(MOC)** | Styrene Butadiene Rubber(SBR)[MOC: AI 6061] |
| **Wheel hub weight** | 70 g |

**Table (a): Specification of the wheel at joint**

**Motor Specification:** The motor selected for this project is a BLDC drone motor. It is a light weight (53g) high performance motor.

Standard – Antigravity T-motor MN 4004 KV 300

Motor weight = 53 g/motor

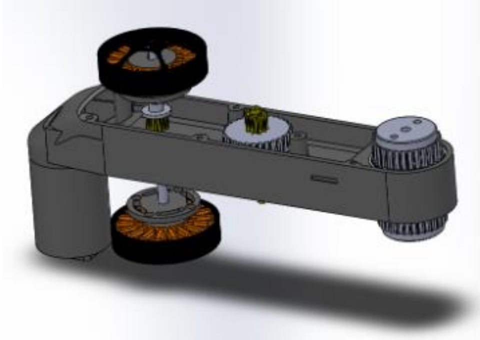
| Test Report | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type | Voltage (V) | Propeller | Throttle | Current (A) | Power (W) | RPM | Torque | Thrust (g) | Efficiency (g/W) | Operating Temperature (C) |
| | | T-Motor 13*4.4"CF | 50% | 0.90 | 22 | 3173 | 0.06 | 311 | 14.40 | 30 |
| | | | 55% | 1.10 | 26 | 3415 | 0.07 | 358 | 13.56 | |
| | | | 60% | 1.40 | 34 | 3660 | 0.07 | 416 | 12.38 | |
| | | | 65% | 1.70 | 41 | 3914 | 0.09 | 477 | 11.69 | |
| | | | 75% | 2.40 | 58 | 4394 | 0.11 | 608 | 10.56 | |
| | | | 85% | 3.30 | 79 | 4876 | 0.13 | 754 | 9.52 | |
| | | | 100% | 4.20 | 101 | 5317 | 0.16 | 895 | 8.88 | |

**Table (b): Data sheet for Test report of T-motor**

| Test Item | 300 | | Weight(Incl. Cable) | 53g |
|---|---|---|---|---|
| Motor Dimensions | 44.35*19mm | | Internal Resistance | 452mΩ |
| Lead | 50mm | | Configuration | 18N24P |
| Shaft Diameter | 40mm | | Rated Voltage(Lipo) | 4-6S |
| Idle Current(22V) | 0.2A | | Peak Current(180s) | 9A |
| Max Power(180s) | 216W | | | |

**Table (c): Motor Specifications**

**Actuator Module:** The upper limb of leg that comprises of a system of 3 gears. Calculations involved in the system:-

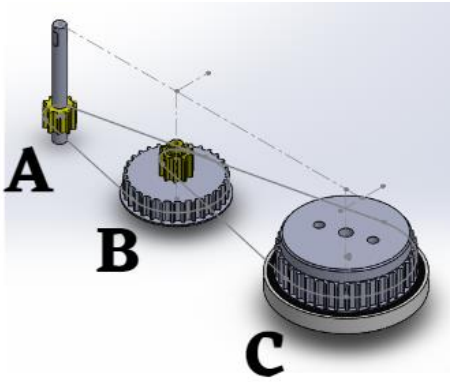


Let, N = Number of Teeth in Gear

D = Diameter of Gear

w = Angular Speed

T = Torque




- Gear Ratio $= \frac{N\ out}{N\ in} = \frac{D\ out}{D\ in} = \frac{w\ in}{w\ out} = \frac{T\ out}{T\ in}$

$N_A = 10$, $N_B = 30$, $N_{B'} = 10$, $N_c = 40$, $w_B = w_{B'}$,

$w_A$ = W degree/s, $T_A$ = T Newton/m

i. Angular Velocity: As we increasing the number of teeth in gears it decreases the angular velocity by 1/12 times the initial value.

$$\frac{N_B}{N_A} = \frac{W_A}{W_B} \to W_B = \frac{N_A}{N_B} \times W_A = \frac{W}{3}$$

$$\frac{N_C}{N_{B\prime}} = \frac{W_{B\prime}}{W_C} \to W_C = \frac{N_{B\prime}}{N_C} \times W_{B\prime} = \frac{W}{12}$$

ii. Torque: As we increasing the number of teeth in gears it increases the angular velocity by 12 times the initial value.

$$\frac{N_B}{N_A} = \frac{T_B}{T_A} \to T_B = 3T$$

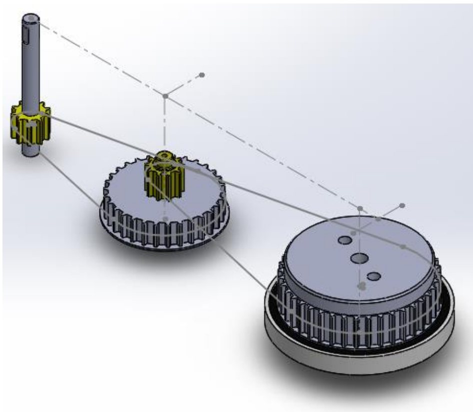
$$\frac{N_C}{N_{B\prime}} = \frac{T_C}{T_B} \to T_C = 4T_B \to T_C = 12T$$

## Specifications of Timing Belt:

| | |
|---|---|
| **Standard Tooth Profile** | AT3 (Arc Tooth 3) |
| **Tooth pitch** | 3 mm |

**Table (c): Belt Specifications**

# Kinetic Simulation-Actuator Module:-



When the quadruped robot moves on the wheel at its joints, the wheel experiences a torque which is in opposite to the direction of the torque provided by the motor. In that case the motor my get burn if the torque experienced by the motor is more than the torque produces by the motor.

Body weight = 2.2 Kg (including motor, battery, 3D printed weight)

Therefore,

Weight per leg = Tyre weight + wheel hub weight + body weight + motor weight

= 783 g

Coefficient of friction = 0.7

Torque (T) = 230 N mm

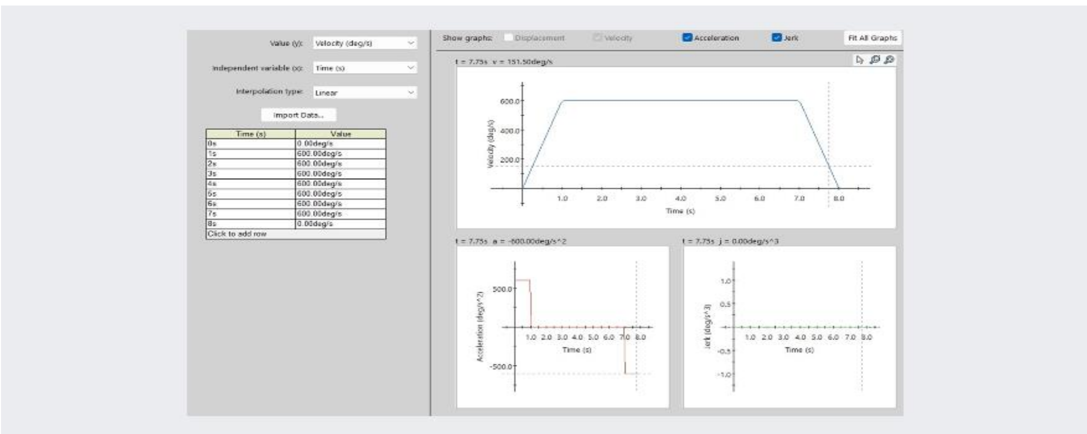
(Reference: Bhupendra's Report (B21ME019))

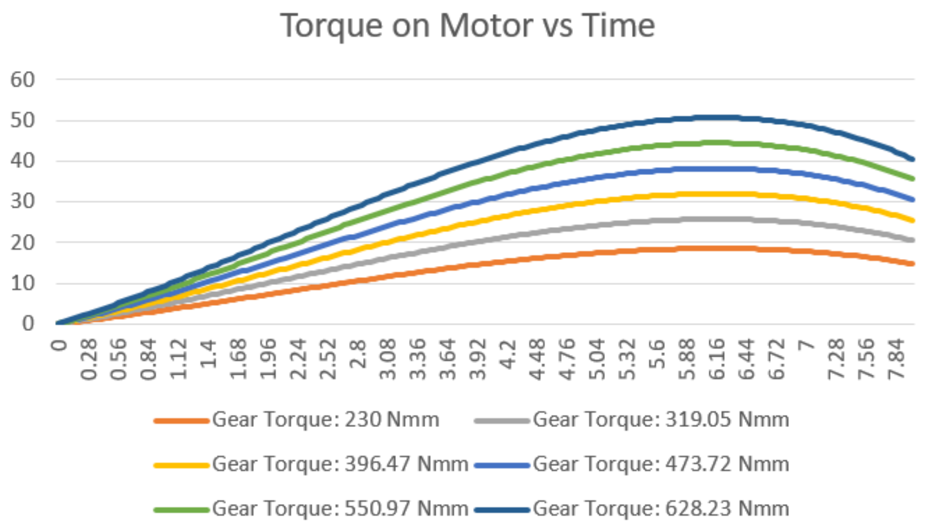
# Visualization of Torque experienced by Motor:-

To find the torque produced by the wheel at joint for different payloads:-

- Weight/leg = 783 g → Opp. Torque = (0.7)x(0.783)x(9.81) = 230 N mm
- Weight/leg = 1033 g → Opp. Torque = (0.7)x(1.033)x(9.81) = 319.05 N mm
- Weight/leg = 1283 g → Opp. Torque = (0.7)x(1.283)x(9.81) = 396.47 N mm
- Weight/leg = 1533 g → Opp. Torque = (0.7)x(1.533)x(9.81) = 473.72 N mm
- Weight/leg = 1783 g → Opp. Torque = (0.7)x(1.783)x(9.81) = 550.97 N mm
- Weight/leg = 2033 g → Opp. Torque = (0.7)x(2.033)x(9.81) = 628.227N mm

Velocity profile of Motor:-






In all the above cases the value of torque is less than 60 N mm. Which means that the motor is capable to handle to torque for the payload range of 5 kg.

## Kinetic Simulation-Full Leg (Fixed End):-

When the quadruped robot raise on its feet at fixed ends due to the torque provide by motor, the motor also experiences a torque in opposite direction.


The value of torque experienced varies when we increase the payload on the robot. So, let's visualise the torque experienced by the motor at the time of raise for different payloads.

Weight per leg = Tyre weight + wheel hub weight + body weight + motor weight

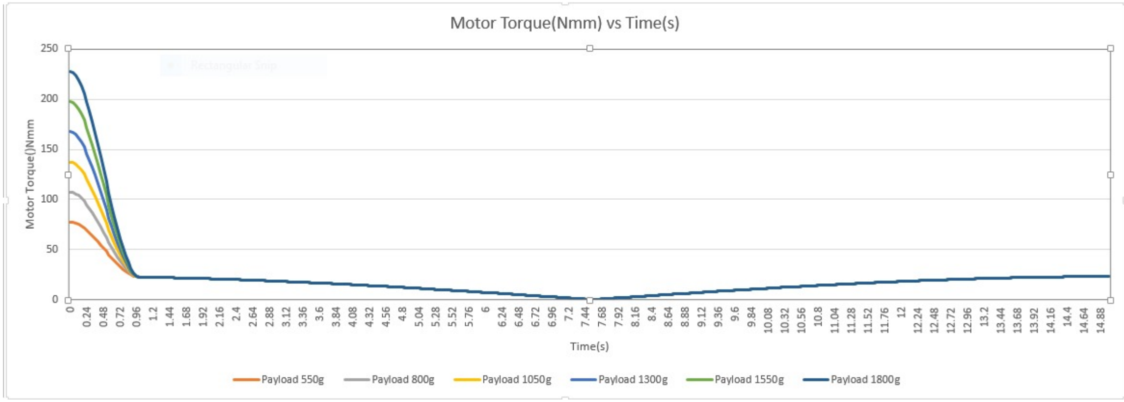
= 783 g

# Visualization of Torque experienced by Motor:-

To find the torque produced by the wheel at joint for different payloads:-

- Weight/leg = 550 g
- Weight/leg = 800 g
- Weight/leg = 1050 g
- Weight/leg = 1300 g
- Weight/leg = 1550 g
- Weight/leg = 1800 g

Velocity profile of Motor: Angular velocity = 100 RPM (600 degree/s)




In all the above cases the value of torque is more than 60 N mm (Max. torque motor can experience). So, in this cases the motor may fail.

## Kinetic Simulation-Full Leg (Free End):-

To calculate the properties in more precise way we can simulate by making lower limb in contact with the stand.


When the quadruped robot raise on its feet due to the torque provide by motor, the motor also experiences a torque in opposite direction.

The value of torque experienced varies when we increase the payload on the robot. So, let's visualise the torque experienced by the motor at the time of raise for different payloads.

Weight per leg = Tyre weight + wheel hub weight + body weight + motor weight

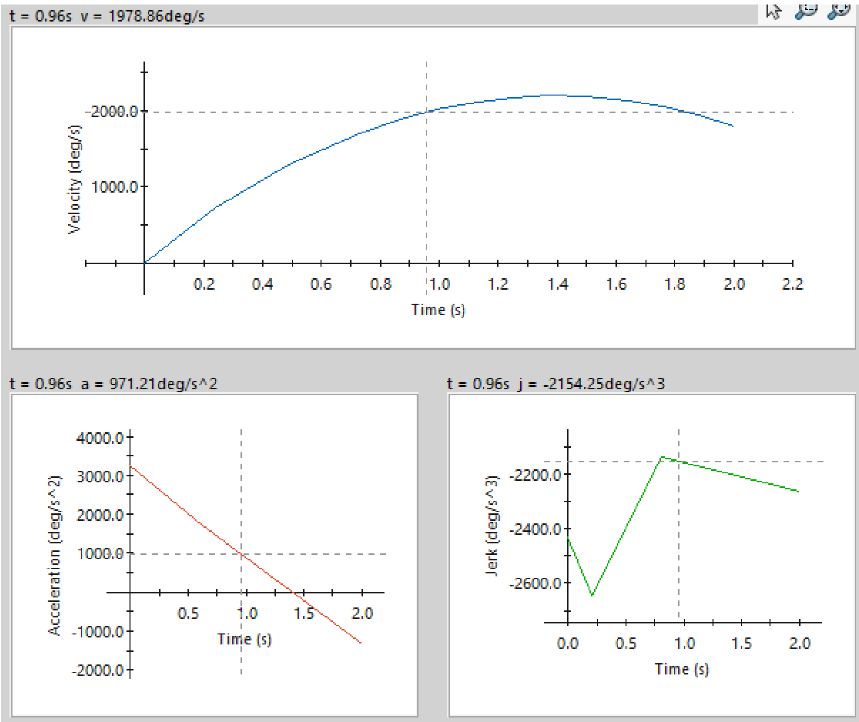
= 783 g

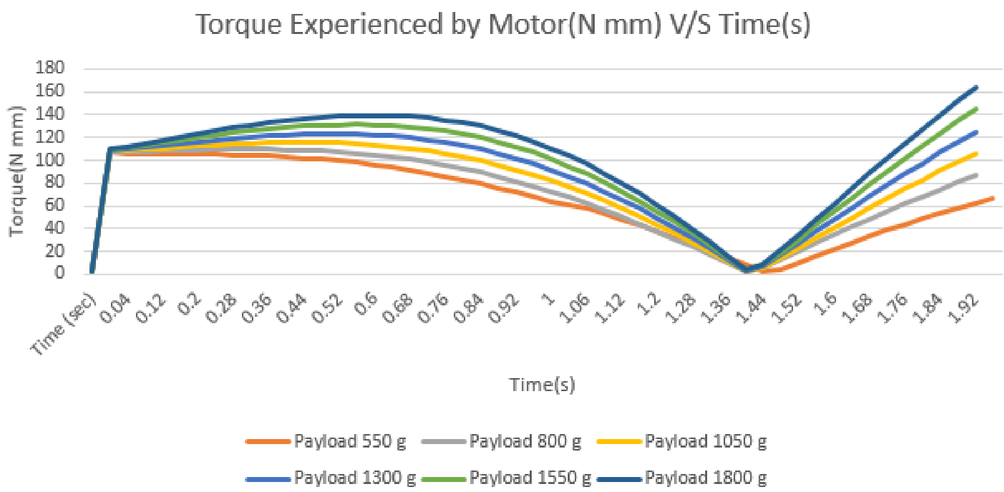
# Visualization of Torque experienced by Motor:-

To find the torque produced by the wheel at joint for different payloads:-

- Weight/leg = 550 g
- Weight/leg = 800 g
- Weight/leg = 1050 g
- Weight/leg = 1300 g
- Weight/leg = 1550 g
- Weight/leg = 1800 g

Velocity profile of Motor:-




In all the above cases the value of torque is more than 60 N mm (Max. torque motor can experience). So, in this cases the motor may fail.

# III. CONCLUSION

The legs of wheeled quadruped robot are successfully designed and simulated in solidworks. By the study of the kinetic simulations we have reached to the conclusion that current specified motor (Antigravity T-motor MN 4004 KV 300) need to be change because it may get fail when it experience opposing torque.