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## I Design of Passing Robot

### I.1 Overall Dimensions and Weight

Table 1: Dimensions and Weight of PR

Sr No	Dimension	Value	Dimension	Value
1	Length	834 mm	Game length	1020 mm
2	Width	825 mm	Game Width	1034 mm
3	Height	843 mm	Game Height	843 mm
4	Weight			15 Kg

### I.2 Type Of Drive

The drive used for the locomotion of the robot is a **three-wheel holonomic drive** made using **Omni wheels**. Three-wheel Omni drive is used because of its simplicity, agility and ease of control. It is made using **Aluminium 6061 square tubes** because of its optimum strength to weight ratio. For automating the three-wheel we have used an **Inertial Measurement Unit (IMU) MPU6050** used which allows the robot to orient itself. For the distances feedback, we have used encoders with dummy wheels to **resolve locomotion along X and Y-axis**.

### I.3 Actuators and Sensors Integrated

- Sensors

Table 2: Sensors Integrated on PR

Sr No	Sensor	Specification	Quantity	Usage
1	Incremental Optical Rotary Encoder	600 Pulses Per Rotation	2	To Control Position of the leg.
2	Intertial Measurement Unit (IMU) MPU6050	3 - Axis Gyroscope 3 - Axis Accelerometer	1	To Control Angular Position of Robot.
3	Ultrasonic Sensor (HC-SR04)	2 - 400cm distance module, 0.3 cm resolution	1	Distance calculation between ball rack and robot.

- Actuators

Table 3: Actuators Used on PR

Sr No	Actuators	Specifications	Quantity	Usage
1	Pneumatic Air Cylinder	8 mm bore diameter, 25 mm stroke length.	1	For gripping the try ball
2	Pneumatic Air Cylinder	25 mm bore diameter, 300 mm stroke length.	1	For linear displacement of the jig to slide the ball in the rotors
3	PMDC Motor	12 V DC, 3000 RPM, Torque: 4 kg-cm	2	For rotating disc wheels
4	Planetary Geared PMDC Motor	12 V DC, 400 RPM, Rated Torque: 4 kg-cm	2	For rotating gripper arms

## I.4 Ball Picking and Passing Mechanism

### I.4.1 Calculations

### I.4.2 Working

#### A. Maintaining the desired distance from the ball rack with proper orientation:

MPU6050 is used for the orientation of pass Robot and for locomotion, Rotary encoder and MPU6050 feedback is used. Ultrasonic sensor feedback is used for the detection of ball and distance calculation between ball rack and robot.

#### B. Gripping and Throwing a ball:

The gripping piston mechanism is used for gripping of the ball. The catapult piston mechanism is actuated for the throwing of the ball towards Try Robot. Range of Catapult mechanism is **7 m** to **7.5 m** height is **90 cm**.

## II Design of Trying Robot

### II.1 Overall Dimensions and Weight

Table 4: Dimensions and Weight of TR

Sr No	Dimension	Value	Dimension	Value
1	Length	<b>855 mm</b>	Game length	<b>1148 mm</b>
2	Width	<b>940 mm</b>	Game Width	<b>1045 mm</b>
3	Height	<b>848 mm</b>	Game Height	<b>848 mm</b>
4	Weight			Kg

### II.2 Type Of Drive

The base frame has been framed with **Aluminium 6061** hollow square pipes of cross-section **19 mm x 19 mm x 1.5 mm** thick. *Aluminium ensures an efficient light-weight frame with uniform weight distribution.* Since Aluminium has low density ( $2.7g/cm^3$ ) compared to other common metals available, it made the robot lightweight while ensuring swift translation and sturdiness of the base. Being Holonomic in nature it enables fast locomotion as well quick response to the change in direction of travel. The three wheeled robot reduces the overall weight of the robot and provides better load distribution over all the wheels.

### II.3 Actuators and Sensors Integrated

- Sensors

Table 5: Sensors Integrated on TR

Sr No	Sensor	Specification	Quantity	Usage
1	<b>Incremental Optical Rotary Encoder</b>	600 Pulses Per Rotation	2	To Control Position of the leg.
2	<b>Intertial Measurement Unit (IMU) MPU6050</b>	3 - Axis Gyroscope 3 - Axis Accelerometer	1	To Control Angular Position of Robot.
3	<b>Potentiometer</b>	10k linear taper 16 mm rotary potentiometer	2	To control ball placing Flap Actuation.
4	<b>Digital Proximity Sensor</b>	<b>0 - 80cm</b> non contact type detection, <b>5V</b>	2	For detecting the kicking ball
5	<b>Ultrasonic Sensor (HC-SR04)</b>	<b>2 - 400cm</b> distance module, <b>0.3 cm</b> resolution	1	Distance calculation between ball rack and robot.

- Actuators

Table 6: Actuators Used on TR

Sr No	Actuators	Specifications	Quantity	Usage
1	Johnson Geared Motor	12 V DC, 60 RPM, Rated Torque: 20 kg-cm	1	For rotating gripper arms.
2	Planetary Geared PMDC Motor	12 V DC, 850 RPM, Stall Torque: 45 kg-cm	1	For rotating gripper arms.

## II.4 Ball Recieving Mechanism

The try ball receiving mechanism resembles a basket-like structure having trapezoid-shaped opening to receive the try ball. The receiving mechanism is covered with nylon fibre net to absorb the momentum of the try ball. The structure is made using aluminium 6061 hollow square pipe since it provides quick manoeuvrability along with proper strength.

## II.5 Try Mechainsm

The try mechanism is mounted just beneath the ball receiving mechanism. The try mechanism consists of a ramp, which is placed at an inclination of  $25^\circ$  to the ground and a flap which holds the ball inside of the try receiving mechanism. Once the try ball is received in the mechanism with the help of the net, the ball will fall on the ramp and slide down through it till it is obstructed by the flap. The rotation of the flap will stop at a point where the distance between the ramp and flap will be just enough to allow the ball to fall in the try spot. At this point, there will be **contact between the flap and ball and the ball and ground as well**. While making a try, the placing flap is actuated using Johnson geared motor. As the **ball must touch the robot and ground simultaneously**, the placing flap's angular movement must be controlled. A **10k Ohm potentiometer** coupled to the motor's shaft is used as feedback to control the movement of placing flap accurately.

- Alternate Gripping and Placing using Gripper:

In case, **if the ball is not received in the basket** and falls in the receiving zone then the ball can be picked up using a pneumatic gripper. The gripper will grip the ball along the major axis and lift the ball using a **12V DC Johnson motor** with a **10k potentiometer** as **feedback**. Then the ball will be released by the gripper in the try spot.

## III Kicking Mechanism

### III.1 Mechanism I

#### III.1.1 Components Used

Table 7: Actuators Used on PR

Sr No	Name Of the Component	Specifications	Usage
1	Rod End Bearing	ID: 10 mm	To accommodate the misalignment of the shaft of the piston, rod end bearing is used. The shaft of the piston rod is placed in a ball swivel of bearing placed inside the outer casing.
2	Pneumatic Air Cylinder	300 mm stroke length 25 mm bore diameter, 10 mm shaft diameter.	To provide angular travel and required force to the hitting part of the mechanism.
3	Stainless Steel Rod	Diameter: 8 mm	It is used as a pivot for the pneumatic air cylinder.
4	Direction Control Valve (DCV)	5/2 DCV	It is used for position control of the air cylinder at the end and starting position only.

#### III.1.2 Principle Involved in the mechanism

The kinetic energy of piston of air cylinder along with the potential energy of kicking link is converted into rotational energy of kicking link which is finally converted to the kinetic energy of the ball.

### III.1.3 Design Calculations

- o The calculation for angular travel of the hitting part of mechanism actuated using pneumatic air cylinder (Fig 3).
- o In angular travel calculation, we are tracing an arc travelled by rod end bearing at the endpoint of the piston rod.

**A:** Initial position of the endpoint of the piston rod.

**B:** The endpoint of the piston rod.

**C:** The pivot point of kicking link.

**D:** The pivot point of an air cylinder.

- o Steps in calculations and deciding the height of pivot for air cylinder and the distance between 2 pivots:

1. Considering the length of the kicking part, an arc is drawn with centre at C with some clearance from the ground.
2. For a given cylinder, 90° angular travel of the hitting part is preferred to impart maximum force and velocity to the kickball. **Angular travel more than 90° is not preferred since for that particular angle, piston motion inside air cylinder is restricted.**
3. A vertical line passing through centre C is drawn, ensuring a 30° angle in forwarding ((B) and a 60° angle in the backward direction (point A).
4. Considering the retracted position of the piston of the air cylinder, an arc taking (A as a centre with the length of retracted position (425 mm) is drawn. Again, extended length (725 mm) of the piston in air cylinder is taken into consideration to draw an arc with centre at B. The point of intersection of these 2 is point D which is actually the pivot point of the air cylinder.

### III.1.4 Working

Two pneumatic air cylinders are mounted on the top of the **support structure** and are connected to the leg. Initially, the piston of the air cylinder is retracted and is connected to the kicking link with the help of a rod end bearing. Just after the robot aligns itself at the required distance, the kick is initialized by actuating **5/2 direction control solenoid valve** and as soon as it gets extended, as per the principle, the kicking link travels an angular arc and finally hits the ball.

## III.2 Mechanism II

### III.2.1 Construction

The mechanism consists of a leg which is used as a hitting.

### III.2.2 Calculation

Initially, using Adams simulation software, the initial velocity that needs to be imparted to the ball so that it passes the conversion post from the desired distance was obtained. This velocity will be imparted to the ball through the impact of the leg. The leg should have a certain minimum velocity while the impact to achieve the desired results. This velocity will be provided by the motors.

To decide the torque and speed output required from the motor, the following energy conservation calculations were done.

$$\frac{1}{2}I\omega^2 = \frac{1}{2}m\nu^2$$

Where,

$I$  = Moment of Inertia of the leg;  $\omega$  = Angular speed of the leg

$\nu$  = Velocity of the ball;  $m$  = Mass of the ball (340 g)

Based on the calculations, two motors of the following specifications are used

- RPM = 840 and Torque = 40 kg.cm

### III.2.3 Working

- Ball Detection and Alignment:

The ball is detected using proximity and after detection ultrasonic sensor gives the distance of the ball from chassis, with

the help of a lateral shifting robot is aligned for kicking.

- Steps for Kicking:

Motors are mounted on the top of the support structure and are connected to the Leg. 600 PPR rotary encoder is used for controlling the leg's angular position. The kick is initialized by moving the leg vertically upwards making an angle of 180 degrees with respect to the structure. Then the motors are actuated, and this makes the leg rotate. Once the leg makes an impact with the ball, the power supply to the motors is ceased. But the leg continues to rotate due to its inertia.