Design Details Document

Robocon India 2020

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Pass Robot :

1. **Overall dimensions** (L x W x H) :
   At start : 646 x 524 x 830 mm
   During Game time : 646 x 524 x 830 mm
2. **Estimated weight :** 18.1 kg
3. **Materials used :** Stainless steel AISI304 , aluminium 6061 , nylon-66, glass fibre, carbon fibre, mild steel, plastic etc.

4. **Type of drive :** Three Wheel Holonomic Omni-wheel Drive.

Three wheel drive is selected because of it's precise control and rich manoeuvrability . In case of 4 wheel drive the contact of wheel with ground may get lost which leads to slippage and potential loss of control. It also induces stress in base of the chassis due to cantilever generated by lifted wheel. 3 wheels always remain in same plane and always maintain contact with ground.

This drive will be **semi-autonomous**. The manual mode of this drive will be controlled wirelessly via PS4 controller. For autonomous navigation, the robot uses feedback from laser distance sensors, MPU-6050 and rotary encoders. Laser distance sensors will be used to sense position of robot w.r.t game field. MPU-6050 is used to maintain the stability during navigation and angular orientation of robot in desired yaw angle during passing phase, while encoders are used to sense individual wheel velocity to calculate robot velocity and it's angle of propagation.

Motors used for drive are **"Planetary DC geared motor 250W 750RPM 18V DC"** with rated torque of 3.83 Nm. Wheels used are of diameter 100 mm. With this motor and wheel combination the robot achieves an acceleration of 2.5 m/s^2.

5. **Pick and Pass Mechanism** :

Introduction:

The **objective of the task** is to pick the rugby ball and pass it to the try robot so that it can score a "**try**". A **pneumatic gripping arm** is used to pick the ball and the widely used **rugby ball pitching mechanism** is used for passing.

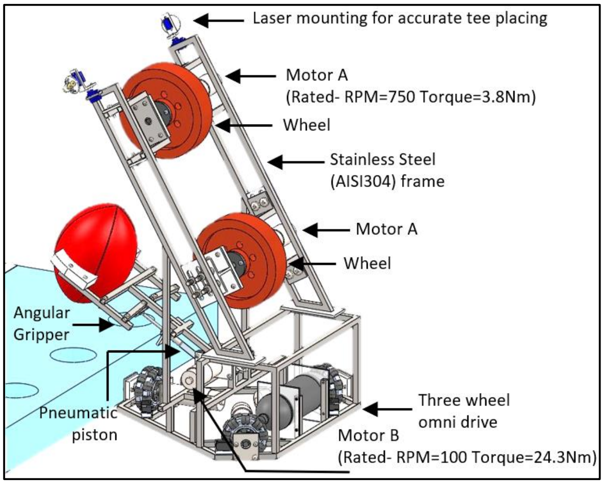


Fig 1 : Pass robot with pick and pass mechanism

A modification of orienting the axis of rotation of wheels parallel to the ground plane is made for easy loading of ball. As per team's game plan **desired throwing range is 7m**.

Working of mechanism :

The passing mechanism works on the principle of **conservation of momentum,**

1. Gripper is opened and inserted around the pass ball kept in rack (Fig 2: Step 1)
2. Gripper is closed and arm is partially lifted to take out the ball from ball rack (Fig 2: Step 2.1 & 2.2)
3. Robot is oriented to face the try robot and wheels start spinning.
4. Arm is further rotated and ball is inserted between the wheels (Fig 3: Step 4)
5. Ball is sucked and immediately thrown out by the wheels. (Fig 3: Step 5)

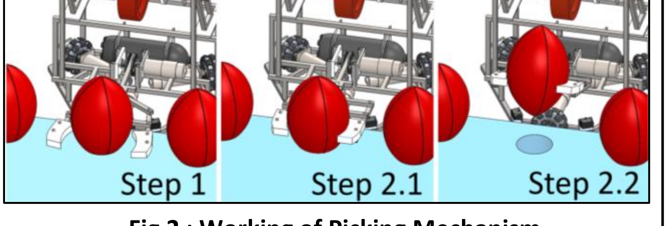


Fig 2 : Working of Picking Mechanism

Calculations/Justification:

The dimensions for gripper are selected such that when it is opened, rest of the balls in the rack remain undisturbed. The gripper is designed to lift the ball using it's **shape as restriction rather than a firm grip** to reduce the torque required for wheels to pull the ball in.

The actuator used for gripper is a pneumatic piston of stroke length 50mm and bore ϕ12mm, operated on 4 bar pressure to generated a force of 45N. This force is sufficient to hold gripper's shape during lifting process. The gripper engages with ball just below the maximum diameter to ensure ball doesn't roll over during lifting process. Gripper design ensures **that ball simultaneously engages with both the wheels** for maximum momentum transfer.

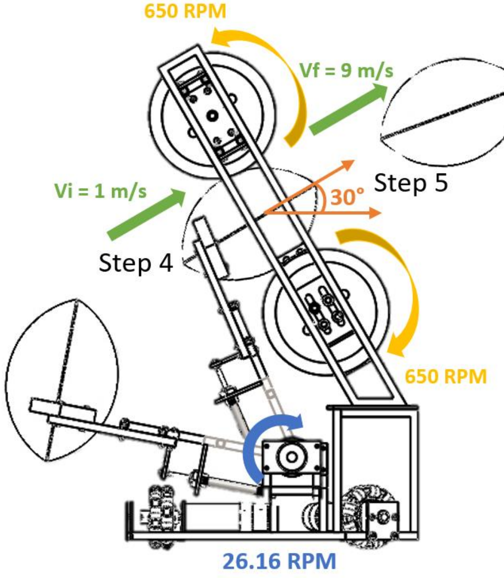


Fig 3 : Working of pick and pass Mechanism

The mass of the gripper and ball is 2.34kg. C.G of gripper with ball lifted is at a distance of 0.219 m from the point at which the gripper is pivoted. Hence, the torque required is calculated as

$$\boldsymbol{\tau = F \times r = m \times g \times r}$$
$$\boldsymbol{= 2.34 \times 9.81 \times 0.219 = 5.02\ Nm}$$

The required RPM for motor is selected to ensure that the ball reaches an initial velocity of 1m/s before getting pulled by the wheels. Here **r** is taken as distance of ball's centre from pivot; r= 365mm

Hence, **required RPM is = 26.16 RPM**

A planetary DC geared motor of RPM 100 and torque 25.52 Nm is selected (motor B).

The launching height of the mechanism is **0.53m** while receiving height will be **0.66m**. The passing mechanism is **set to launch the ball at an angle of 30°** considering required range and to achieve shorter flight time. By using this data and basic projectile equations we need an initial launch velocity of approx. **9m/s.**

The air resistance doesn't play a significant role during this motion due to **symmetric air foil** like shape of the rugby ball.

The **coefficient of restitution was calculated to be 0.7** , after conducting repetitive practical tests. All the above data is used to determine required linear velocity of wheels by using below formula

$$2 \times M_{roller} \times V_{i_{roller}} + M_{ball} \times V_{i_{ball}} = [2 \times M_{roller} \times V_{f_{roller}} + M_{ball} \times V_{f_{ball}}]$$

and is found to be = 6.06 m/s. Hence, motor with **578RPM and wheel of ϕ200mm is required.** The mass of the wheel is kept higher to ease the momentum transfer process. An acceleration of 0 to 578 RPM under 0.5 seconds is desired hence,

$\boldsymbol{\tau = \alpha \times M.I.of\ wheel}$ (calculated using SolidWorks)

$$\boldsymbol{= \left(\frac{578 \times 2\pi}{0.5 \times 60}\right) \times 0.00371 = 0.45Nm}$$

Hence, **Planetary DC geared motor of 750RPM and torque 3.83 Nm** is selected (motor A).

As the RPM of the wheels can be controlled electronically, attaining variable target range is easy for this mechanism.

Try Robot :

1. **Overall dimensions** (L x W x H) **:**
   At start : 889 x 837 x 557 mm
   During Game time : 1116 x 837 x 835 mm
2. **Estimated weight :** 18.5 kg
3. **Materials used :** Stainless steel AISI304 , aluminium, nylon-66, glass fibre, carbon fibre, mild steel, rubber etc.

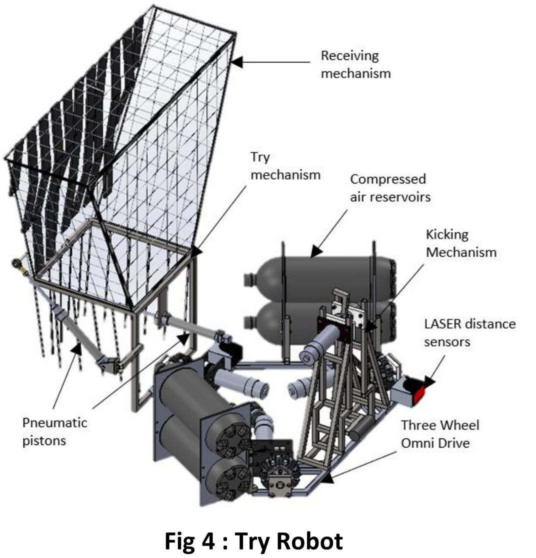


Fig 4 : Try Robot

4. Type of drive : Three Wheel Holonomic Omni-wheel Drive.

The reasons for selecting three wheel drive for try robot were the same as for pass robot. The motors used for drive are **"Planetary DC geared motor 250W 750RPM 18V DC"** with rated **torque of 3.83 Nm**. A **gear reduction of 1:2** is used at the output of motor to get **1500 RPM and torque of 1.915 Nm**. Although this reduction reduces the acceleration of the robot but enhances its maximum and average speed necessary for navigation. The robot is semi-autonomous. For manual mode PS4 controller is used while for the autonomous mode, sensors same as that for pass robot are used.

5. Receiving Mechanism :

Introduction:

The **objective of the task** is to receive the ball from the passing robot and handle it over to the try mechanism. **Trapezoidal frame with rubber strips** for damping of ball is used. A **nylon net** is used for guiding the ball to the try mechanism.

Working of mechanism:

The process is illustrated by below diagram :

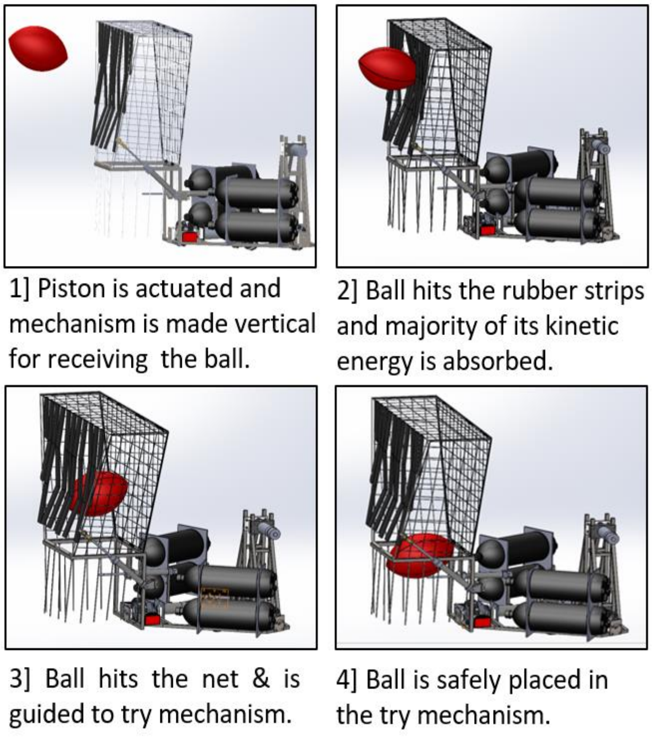


Fig 5 : Working of Receiving Mechanism

Justification:

Entrance of the receiving mechanism is equipped with rubber strips which will help to **retard velocity of the ball**. A high strength nylon net is used to enclose the remaining part of the receiving mechanism. Maximum kinetic energy of the ball is absorbed by the rubber strips and hence, the **ball doesn't bounce back** after hitting the net. The thickness of the rubber strips is decided by practical result analysis.

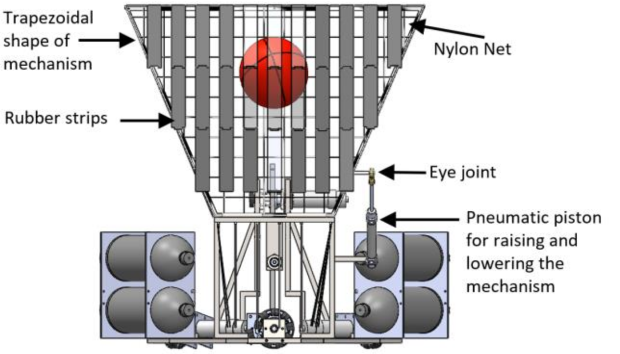


Fig 6 : Front View of Receiving Mechanism

Net is used to reduce weight of the mechanism and potential air drag. It is arranged such that after the ball strikes the net, due to gravity it will roll along the net & come to **rest in try mechanism**. The passing mechanism will be aimed to target only **the upper half of the receiving mechanism** while the lower part is used to guide ball to the try mechanism. Hence, a trapezoid shaped mechanism is designed keeping in mind the compactness and at the same time **maintaining maximum coverage area** for receiving.

Lower side of the trapezoidal frame is pivoted and actuated by a pneumatic piston. **The trapezoidal frame can hence be raised during receiving and lowered after the ball is received** (Ref Fig 7**).** Keeping frame lower eases the controlling of robot.

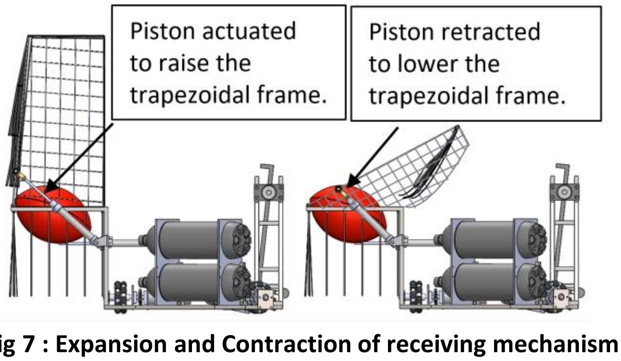


Fig 7 : Expansion and Contraction of receiving mechanism

6. Try Mechanism :

Introduction:

The **objective of the task is** to score a try while abiding to the rules. The received ball is held using an **actuated piston** in a square frame. The piston is retracted during the process of scoring a try to place the ball in try spot.

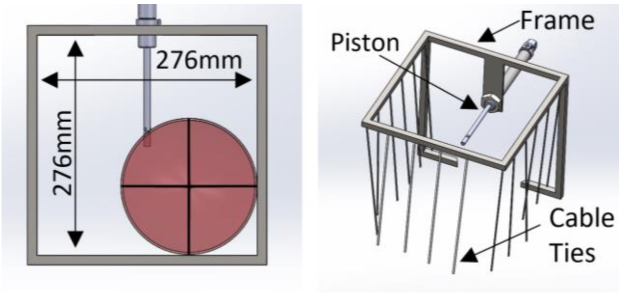


Fig 8 : Try Mechanism

Working of mechanism:

1. The ball is maintained in the frame by using a pneumatic piston.
2. While scoring a try, the piston will be retracted and due to the gravity ball will start to fall into the try spot.
3. Try ball touches the surface of try spot for the first time, the cable ties attached to the mechanism are in contact with ball.
4. Robot moves backwards and ball remains in try spot.

This process is illustrated by below diagram :

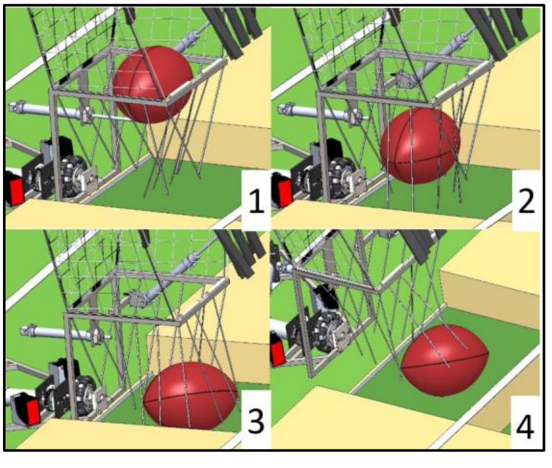


Fig 9: Working of Try mechanism

Justification:

The inner dimensions of square frame are 276 x 276 mm. The size is selected so that ball received in any orientation won't affect the working of mechanism.

Piston of stroke length 100mm is used. When it is actuated it prevents the ball from falling down. **Ball in any orientation can't pass through the void spaces** (ref Fig 8) of the mechanism. Piston when retracted, quickly clears the path for the try ball for a "**successful try**". **Cable ties** are attached to all sides of the frame pointing inward (ref Fig 9) . Cable ties ensure that (FAQ 0-19-3) when the try ball touches the surface of the try spot for the first time TR and try ball are in contact. It also ensures that the ball doesn't touch the boundaries of the try spot, following the **"rulebook 0.19.a & 0.19.b"** . The cables are lightweight and flexible so when the robot moves back they don't pull the ball out of the try spot. Hence, ball remains within the try spot **(rulebook 0.19.c).**

7. Kicking Mechanism :

Introduction:

The **objective of the task** is to kick the ball through the conversion post while abiding to the rules. A leg having cylindrical billet at one end and rotated using a planetary geared DC motor is used for the mechanism.

Working of mechanism:

Initially the leg is kept at an angle of 100° w.r.t ground plane. The motor is then powered to rotate the leg in clockwise direction. The leg sweeps an angle of 235 degree to hit the ball and **transfer its momentum to the ball**. The ball gains required initial velocity from the transferred momentum. This process is illustrated by below diagram :

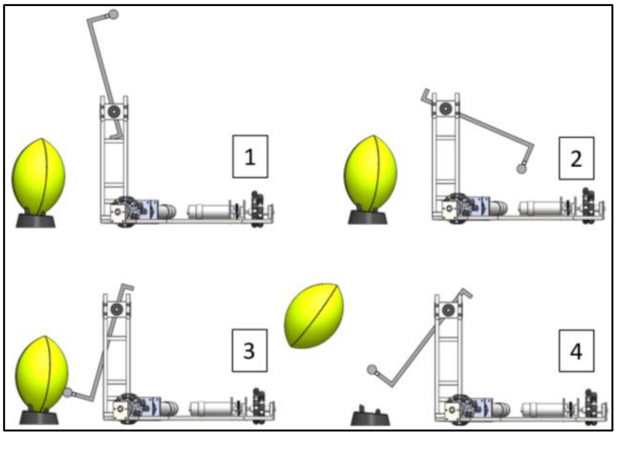
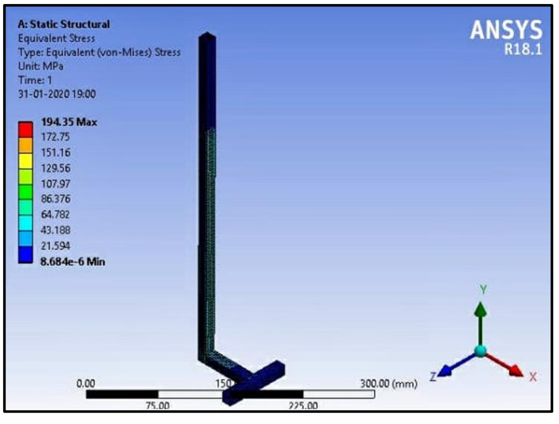


Fig 10: Working of Kicking mechanism

Justification/Calculations :

The initial position of leg is selected by considering the desired momentum gain and velocity, **without violating the rule (0.20.a).** An angular mechanism for kicking is selected over a linear mechanism due to the fact that in **angular actuation** the actuation speed can be varied accordingly.

The material to be selected for the leg of the mechanism was first tested using **ANSYS software** (ref Fig 11). Comparing Al6061(1.5mm thick) and SS304(1 mm thick), it was concluded that **SS304** should be used for the mechanism, considering the parameters of yield strength and density.



<u>**Fig 11 : Ansys report of kicking leg**</u>

To gain maximum points for the kicking process, the ball is to be kicked from **kicking zone 3**. The ball is placed such that the ball and the post are at a distance of **8.6m** from each other. Using projectile trajectory equation,

$$y = x \cdot \tan\theta - \frac{g}{2 \cdot u^2 \cdot (\cos\vartheta)^2} \cdot x^2$$

Substituting,

x = 8.6 m (distance between ball & H post)

y = 2.5 m (height at which ball passes H post)

θ = 45° (To get maximum range)

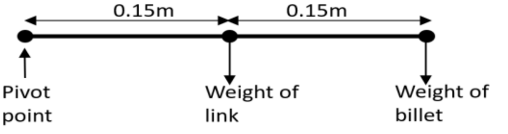
We get $\boldsymbol{u}$ **= 10.9 m/s.**

Hence, the velocity required for the leg so that the ball attains initial velocity of **10.9 m/s**, is calculated using **conservation of momentum** formula,

$$v_{leg} = \frac{[u \times (m_{leg} + m_{ball}]}{[m_{leg} \times (1 + e)]} = \frac{10.9 \times 0.85}{0.5 \times 1.8}$$

$$= \mathbf{10.29 m/s}$$

As the impulse of the leg increases, the velocity of the ball also increases. The mass of the leg also includes the **mass of the cylindrical billet** (**450g**) that is added at the end. Considering the force and dimension values, the length of the leg was estimated and varied. Based on observations and related calculations, a **leg length of 30cm** is finalized. Converting the velocity of leg into required RPM, considering **leg length to be 30 cm**, an RPM of **328** is required. Required torque of motor is calculated as,



Torque = (link weight x distance) +
(billet weight x distance)
= (0.1056 x 0.15) + (0.5 x 0. 3)
= 0.166 Kg-m = **1.628 Nm**

To satisfy these conditions, the planetary DC geared motor of RPM of 750 and rated torque of 3.83 Nm is used.

The tee is placed at a suitable distance from the mechanism considering practical observations during testing. The results are obtained **proportional to hitting surface area** and height of point from the base. The ball is placed along its length, reason being, due to **initial spin along its long axis** and minimum air resistance due to the **Gyroscopic and Magnus effect**. Also, **a class 2 laser** is provided on the pass robot to point the position of Tee. This helps the pit crew member to place the Tee accurately.

According to the rulebook, the hitting surface must be flat or convex.

The following points were analysed while selecting the surface.

1] Accuracy of hitting the projection point
2] Air drag
3] Manual loading accuracy
4] Force distribution

Based on the results obtained **convex surface** is implemented. According to **"rulebook 20.b" flexible material is not used** and the material mild steel with the **least deformation parameter is** selected.

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