DD-ROBOCON 2020

DESIGN DETAILS DOCUMENT

ABSTRACT

This Document presents the solution ideas proposed by the NIT Durgapur team for DD-Robocon 2020. The design of two robots, namely Pass Robot (PR) and Try Robot (TR) is discussed in details.

1. Design Detail of Pass Robot (PR)

Passing robot is designed to perform 'Ball Picking and Passing'. A manually controlled gripping and shooting mechanism are synthesized for this purpose. Overall dimensions of PR are 970mm x 970mm x 860mm. Total Estimated weight is around 17.3 Kg.

1.1 Drive Selection:

The movement of the Passing Robot (PR) is accomplished by holonomic control of four-wheeled omni directional drive, given the previous experience of the team in DD-Robocon. Omnidirectional wheels have become popular for mobile robots, as they allow the bot to move on a straight path from a dead stop, without having to rotate prior. Moreover, translational motion along any desired path can be combined with rotation, so the robot arrives at its destination at desired angle (orientation). Double aluminium 152mm omni directional wheels are to be assembled on a base frame made up of T-slotted 4040 aluminium extrusion channels (as these extrusion channels offers ease of assembly and convenient installation) in a 45-degree cross configuration, to get a resultant torque of about [(2.81~2.83)T], where "T" is the Torque generated by a single DC Motor.

Since the team aims to complete the task in the minimum possible time, so accordingly the DC motor variables were calculated which depends on factors like number of wheels, dimension of wheels, weight of the robot, traction of the wheels. Weight of robot is estimated to be 17.3kgs and traction between wheel and the arena plyboard surface is in the range of 0.65~0.75. Using these values, min torque and rpm calculations is done and as a result a HD Planetary DC geared 468rpm 24V 72.6N-cm Motor is selected as the main driving motors.

1.2 Ball Picking and Passing Mechanism:

The first and the foremost task for Passing Robot (PR) is to reach the Ball Rack from Passing Robot Start Zone (PRSZ) and then to pick out the Rugby ball from the rack. A ball picking mechanism is synthesised which is based on gripping with the help of a linear actuator. This gripping mechanism consists of two claws hinged on the main(lifting) arm and the ends of these claws are connected to the linear actuator with a prismatic joint (one for each claw). The prismatic joint will enable the end effectors to open and close for gripping. Now as all these tasks are to be semi-autonomous in nature so we need to take care of the fact that the position of other balls (than that under gripping consideration) remains uninterrupted. Accordingly, geometrical calculations are done taking claw(link) length into consideration and thus a linear actuator of 50mm stroke (DC 12V 1500N 6mm/sec) is selected, which when at its full stroke, occupies a distance of 300mm above the surface of the ball rack. Hence for this arrangement, the claw opening is constrained so that while gripping a particular ball from the ball rack, no nearby ball is disturbed. Another challenge is the non-uniform cross section of rugby balls, so to pick up the ball from the rack the end effectors are designed strategically, i.e. the perimeter of end effector at closed position is around 470~490mm which is slightly less than the girth of size 3 rugby balls.

Now this approach will help us in successful gripping of the Ball.

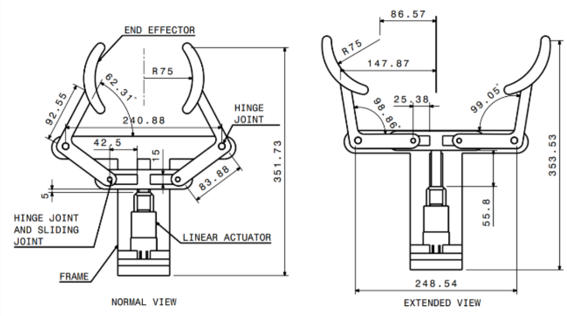

Fig.1.1: Geometrical view of Gripper Mechanism

After the ball is gripped strongly enough (i.e. with sufficient contact force by the end effectors), the next immediate task is to take out the ball from the rack. The main(lifting) arm, which houses the complete gripper mechanism (assembly of claws, joints, end effectors along with the gripped ball), it rotates with the help of a metal gear servo motor (52gm 4.8V-7.2V 13kgcm-15kgcm) mounted on the base of Passing Robot (PR). This gives our Gripping mechanism a 2-DOF configuration one actuated by linear actuator and other by metal gear servo motor. Frames(links) for gripping mechanism are made up by 0.5x0.5 inches aluminium section and hence we estimate the weight of the assembly (gripper with ball) which is required for selection of metal gear servo motor.

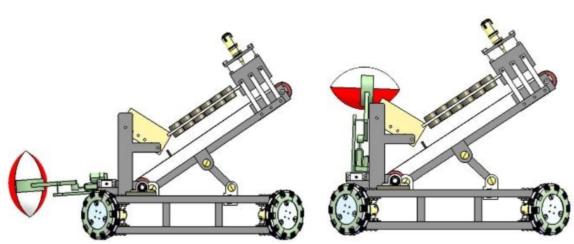

Fig.1.2: Ball gripping and lifting mechanism

Passing Robot (PR) needs to pass the Try ball to Try Robot (TR), which is at the Receiving Zone. Passing mechanism is inspired by the mechanism used in dual heavy wheel bowling machine. So, this mechanism includes a pair of adjacent ball ejecting 100mm heavy-duty wheels with its circumference lined with 10mm thick silicon-rubber material to increase traction between the two contacting surfaces. These heavy-duty wheels are mounted on a frame for axial rotation (using high rpm DC motor rotating in opposite sense to each other) in a common plane, and the gap between the wheels are slightly less than the diameter of the ball (i.e. it has to be less than ~170mm). This machine transfers the kinetic energy to the ball by frictional gripping of the ball between two rotating wheels. The frame over which these wheels and motors are mounted, is provided with a tilting assembly so that the angle of throw can be adjusted to cover desired distance. For this the launching frame is connected with a link to the base frame through a hinge joint, this link can slide over the base frame, and can be adjusted to get proper angle of launch.

Some necessary projectile calculations are done to calculate the high rpm DC motor variable for a successful throw over a distance of 2500mm from Passing Robot (PR) to Try Robot (TR) from their respective zones. From CAD model, the difference between height of the point of throw and point of receive is around 160mm and hence following two equations are solved,

$$\frac{2.5}{V\cos 45} = t \qquad \ldots (1.2.1)$$

$$0.16 = V\sin 45 \times t - 0.5 \times 9.8 \times t^2 \quad \ldots (1.2.2)$$

for 45deg angle of throw and we get $V = 5.119$ m/sec. Now the velocity attained by the ball at the point of throw (V) is given by

$$V = \frac{V1+V2}{2}$$

where $V1$ and $V2$ are velocity at point of contact of two heavy-duty ball ejecting wheels assuming no-slip condition to be true. Now as both the wheels are rotating with same speed, we get the minimum angular velocity required for successful throw as $\omega = V/(0.05 + 0.01)$ and hence the minimum $N = 814.714\text{rpm}$. Thus, a Planetary Gear DC Motor (12V

1350RPM 20 N-cm) is selected (one for each wheel).

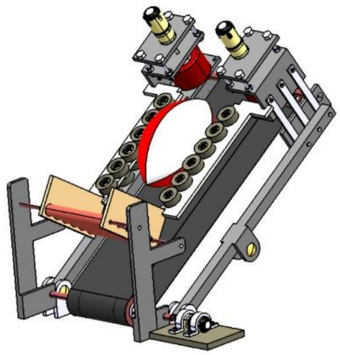

Fig.1.3: Ball feeding and passing mechanism

As the speed of these heavy-duty wheels, trajectory, momentum imparted is pre calculated for a particular orientation of the ball so the ball needs to be fed in the passing mechanism in that predetermined orientation (i.e. along the direction of its major axis) and this is achieved by using a carrier which is driven over a small conveyer belt assembly. This belt assembly is such that both driving and driven end of the belt has a 2-rotor system, driving end is coupled with a 12V DC 500 rpm motor and is mounted over the base of Passing Robot (PR) and driven end rotors are mounted below the two heavy-duty wheels (i.e. with the tilting assembly) so that for any change in angle of launch, the belt plane (hence the feeding direction) is always parallel to the plane of heavy-duty wheels. Now to specifically ensure the fact that ball should be fed along the direction of its major axis, it is dropped from the gripper at a position above the conveyer belt where it first slides over the conveyer roller assembly which guides it to the carrier present over the belt. Also, to restrict any sideways motion of the ball during its movement on the belt, a guide is provided with small rollers along the length of the feed.

2.Design Detail of Try Robot (TR)

Try Robot is designed to perform receiving, trying and Kicking action. For this three different manually controlled mechanisms is synthesized. Overall dimensions of TR are 930mm x 970mm x 1080mm. Total Estimated weight is around 14.6 kgs. A Manual control is designed where PS2 Wired DualShock Remote Controller, connected to Arduino mega(atmega2560) controller, controls the base motors (in both the robots).

2.1 Drive Selection:

The movement of the Trying Robot (TR) is also accomplished by holonomic control of four-wheeled omni directional drive, keeping same advantageous points in mind as discussed earlier. As estimated weight of Try robot is slightly less than Pass robot, similar driving motor variable calculations is done and as a result same HD Planetary DC geared 468rpm 24V 72.6N-cm Motor is selected.

2.2 Ball Receiving Mechanism:

The Ball thrown by the Passing Robot (PR) is to be collected by Try Robot (TR) in the receiving zone and for that, Try Robot (TR) is fitted with a custom-made collector structure of broad square opening of 400mm x 400mm at a height of about 800 mm from the ground. The square opening of the collector is designed sufficiently large to catch the ball for both the calculated and even deflected trajectories to some considerable extent. The collector, supported from base of the robot, is made up of aluminium frame which is covered by net from the four sides to keep the ball within the frame and guide it to base of the collector. Another important point considered in the design is that, along the height of the collector, cross sectional dimensions are never smaller than 255mm x 255mm (length of size 3 rugby ball), as to ensure that the collected ball never gets stuck in the collector before reaching the base. The large square opening is mounted at a certain angle from vertical plane so that its area vector and velocity vector of incoming ball are parallel (counter) at the point of receive in order to increase the probability of successful catching (which we get by extending the projectile calculations done in section 1.2). It is obvious from the design of ball receiving mechanism that for a successful receive both the robots have to be aligned properly in such a way that point of throw and point of receive are in a same plane, and as both the robots are manually controlled, it depends on the precision of alignment shown by the operators.

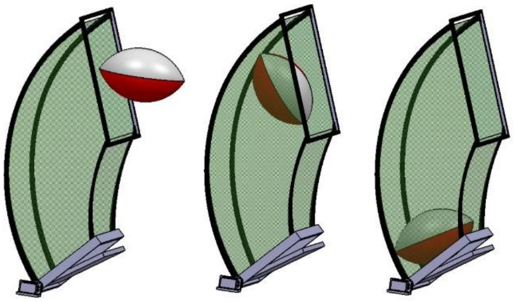

Fig.2.1: Ball Receiving collector

2.3 Trying Mechanism:

After successfully collecting the ball in receiving zone, the robot will move to one of the Try spots to score a Try. The base of the collector is provided with a flap to hold the ball until the Try Robot (TR) reaches the try spot. This flap is actuated by a metal gear servo motor (52gm 4.8V-7.2V 13kgcm-15kgcm) which is mounted on the base of the robot i.e. at a height of 75mm which is very close to the ground and it is important, as when the ball rolls out over the flap, its motion is controlled in such a manner so to create an instant that when the Try Ball touches the surface of the Try Spot for the first time, TR(servo controlled flap opener) and Try Ball remains in contact with each other. This slow and controlled flap opening is also important to avoid the ball from touching the boundaries of the Try Spot.

3.Design Detail of Kicking Mechanism

Kicking of the rugby ball through the conversion post is the most crucial task in this edition of Robocon, and accordingly a simple yet legitimate mechanism is synthesized. This kicking mechanism, mounted on Try Robot (TR), employs elastic energy stored in stretched *bungee cords* for the kicking of the ball. A 750 mm, single DOF kicking leg is purposely designed to transfer this energy to the ball placed over tee on the ground. This kicking leg is mounted with the help of 20mm inner diameter ball bearing on two supporting frames which is directly connected to the base of the robot in such a manner that kicking leg is in the middle of the geometry. Other important points considered for kicking leg design are that the striking face is convex in nature and mass distribution of the leg increases with the increase in distance from the bearing joint (so as to get centre of mass as close to ground as possible). *Bungee cords* arrangement is in such a way that two ends of the cords are fixed with the base(support) on either side and in the middle it is wrapped around the kicking leg at the height of 360 mm from the striking face so that when kicking leg is pulled backwards, the *bungee cords* starts storing energy and gives us required kicking action when set free.

A DC motor driven assistive mechanism is also synthesized in order to pull the kicking leg backwards. High strength nylon ropes with one end connected with the kicking leg are to be wound over a 60 mm pulley using a high torque low rpm DC motor and held in loaded position by a custom-made clutch (teeth and slot spring loaded type-Fig 3.1). The clutch is released by two 12V DC KK-P50/30 60kg Lifting Solenoid Electromagnet. A manually controlled signal is used as a trigger to ensure that the kicking leg is not fired until the ball is close to the optimum position. As before starting the kicking process, the kicking leg will be in loaded condition and hence will be completely inside the space above the main base of the Try Robot(TR), ensuring that the orthogonal projection to the field of the robot do not overlap with the orthogonal projection to the field of the ball & tee.

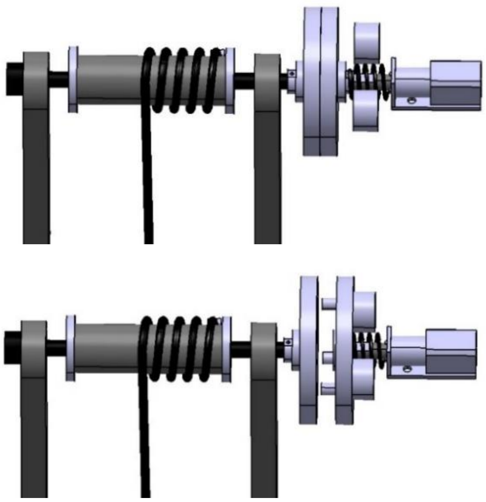

Fig.3.1: Electromagnetic Clutch

A Simulink Multibody model is simulated for necessary minimum torque and angular velocity (from Kicking Zone 3) in order to select the most suitable DC motor variable for loading purpose, whose result are shown in Fig.3.2.

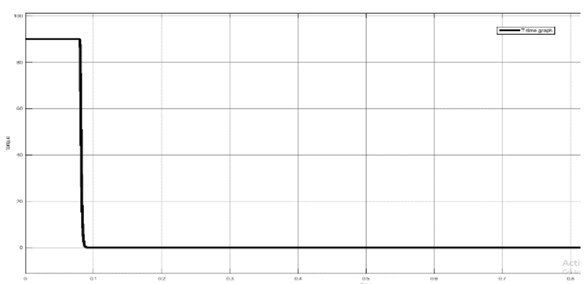

Fig.3.2(a) Variation of Torque at bearing with time

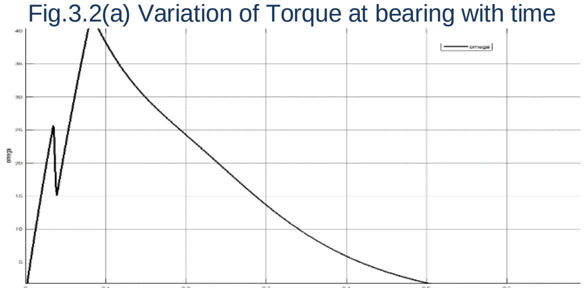

Fig.3.2(b) Variation of angular velocity of kicking leg

From the results we learn that torque required (T_{result}) at the bearing joint of leg for successful kicking of the ball from KZ3 is around 90 N-m and following torque balance equation (3.1) is formulated:

$$(n \times k \times s) \times R_b = T_m \times \frac{Rs}{Rp} = T_{result} = 90 \text{ N-m}$$

Where,
n = number of *Bungee Cords*
k = stiffness of *Bungee Cords*
s = elongation
R_b = distance of *Bungee Cords* on kicking leg from bearing = 390mm
T_m = required torque of motor
R_s = distance of Nylon ropes on kicking leg from bearing = 660mm
R_p = radius of pulley = 30mm.

From above equation we get T_m = 4.09 Nm and thus a Planetary Geared BLDC Motor 85Kg-cm 40rpm 52W is selected (taking transmission efficiency into consideration).
Also,

$$\frac{1}{2} \times nk \times s^2 = \frac{1}{2} \times I \times \omega^2 \quad \text{... (3.2)}$$

I = moment of inertia of Leg (design parameter)
ω = angular velocity of kicking leg
From these two equations we get,

$\omega = \frac{230.76}{\sqrt{nkI}}$ (from which 'nk' value is selected).

REMARKS

Although the dimensions of both the robots are within the limits, still precautionary measures are taken while fabricating the robots as estimated dimensions are very close to the maximum value. And also, some design parameters for Ball Receiving collector like size of the broad opening, the angle of opening can also be adjusted in order to increase the probability of successful 'Receive'.